PHASE I
WATERSHED ASSESSMENT &TMDL
FINAL REPORT

COTTONWOOD LAKE/ MEDICINE CREEK
FAULK, HAND, SPINK COUNTIES, SOUTH DAKOTA

South Dakota Watershed Protection Program
Division of Financial and Technical Assistance
South Dakota Department of Environment and Natural Resources
Steven M. Pirner, Secretary

March, 2001

SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM ASSESSMENT/PLANNING PROJECT FINAL REPORT

COTTONWOOD LAKE/ MEDICINE CREEK WATERSHED ASSESSMENT FINAL REPORT

By

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Executive Summary

PROJECT TITLE: Cottonwood Lake/ Medicine Creek Watershed Assessment

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SUMMARY ACCOMPLISHMENTS

Cottonwood Lake is a natural glacial lake located on Medicine Creek in Spink County. Medicine Creek drains portions of Faulk, Hand, and Spink counties totaling 135,223 acres to form the 1,649-acre lake. The outlet for the lake has been modified over the years to hold the lake at a higher level. The most recent work was completed in 1989 when the highway on the north end of the lake was rerouted and a new cement weir was installed under the new road.

In addition to its listing on the South Dakota 1998 303(d) list for high and increasing TSI values and pH, many of the property owners and users of the lake have expressed concern over the intense algae blooms that occur in the lake. These blooms create an undesirable appearance and are accompanied by unpleasant odors. The object of the study was to locate areas within the watershed that are contributing to the eutrophication of Cottonwood Lake. These portions of the watershed will then be targeted for improvement in a 319-based implementation project. The study was conducted from May of 1999 through May of 2000. It utilized water quality monitoring data as well as landuse modeling. Both the Agricultural Non Point Source (AGNPS) model and the Pacific Southwest Inter-Agency Committee (PSIAC) model were used to assess landuse in the watershed.

Results

The macrophyte survey found that the density and diversity of aquatic macrophytes in the lake were low. Emergent macrophytes were also sparse when compared to other area lakes. Several factors may have contributed to the lack of aquatic macrophytes in the lake. The presence of large numbers of carp, severe wind-induced turbidity (inhibits light), and wave action that causes mechanical damage to plants that prevents the establishment of large beds of macrophytes.

A survey of the property owners at Cottonwood Lake provided information on cabin usage as well as individual wastewater facilities around the lake. Many of the cabins are located on soils that are not suited for septic drainfields due to slow percolation rates. Other dominant soils in the area are sandy and well drained, which allow phosphorus leaching when located in close proximity to the lake.

Tributary sampling data revealed that large loads of nutrients and sediment were entering the lake through the primary tributary, Medicine Creek. These loads of nutrients and sediments were often accompanied by large concentrations of fecal bacteria, an indicator of warm-blooded animal waste. Some sites in the drainage area exhibited concentrations that exceeded the state standards for their beneficial uses. Loads discharging from Cottonwood Lake were often smaller than those entering the lake, suggesting an accumulation of nutrients in the lake. The exception to this was the sediment load leaving the lake, which was larger than the load entering the lake, suggesting bank stability and erosion problems.

Water quality monitoring in Cottonwood Lake was conducted on a monthly basis throughout the project period. Inlake water quality testing showed that the lake conditions are not supporting their beneficial uses. Individual lake parameters were often found to be at or near their maximum allowable limits. With reasonable reductions in nutrient loads, the beneficial uses may be restored.

The AGNPS feedlot subroutine identified 19 feedlots that were contributing excessive phosphorus to Medicine Creek. These phosphorus loads enter Cottonwood Lake and contribute to the eutrophication problems that exist there. PSIAC provided information on rangeland and cropland condition as well as potential reductions in the nutrient and sediment loading to the lake that may be achieved with the implementation of Best Management Practices (BMP).

A sediment survey of the lake indicated approximately 4,799,050 m^3 of sediment has accumulated in the lake basin. Elutriate tests showed no signs of pesticides in the sediment. Sediment accumulation varied in depth from .3 to 2 meters. Medicine Creek delivered the majority of this sediment while the remainder entered the lake from shoreline erosion. Many shoreline areas around the lake have experienced increased erosion as a result of the raising of the lake level and the large volume of runoff in the recent wet years.

Recommendations

The following list of restoration alternatives should not be considered to include all possibilities, nor are they listed in order of priority. This list includes procedures, which have proven effective in other watersheds and might result in improvement if properly applied at Cottonwood Lake and in the Medicine Creek watershed above the lake.

1. Information/ Education Program

2. Septic System Management
3. Lake Shore Stabilization
    a. Sloping and revegetating the cut banks
    b. Macrophyte Establishment
4. Animal Nutrient Management Systems
5. Rangeland BMP
    a. Grazing and Rangeland Management
    b. Alternative Livestock Watering Sources
    c. Windbreak/ Shelterbelt Establishment
6. Cropland BMP
    a. Grassed Waterways
    b. Crop Residue Management
    c. Filter Strips
    d. Integrated Crop Management
    e. Conservation Crop Rotation
7. Stream Bank Stabilization

Implementation of these BMPs will result in a reduction of delivered sediment to Cottonwood Lake by 8%. This will also reduce the delivered phosphorus load by 44% with an implicit margin of safety. The result will be a shift in average lake TSI values from non supporting to partially supporting. The reduction in phosphorus will also shift the lake from nitrogen limited to phosphorus limited. The pH in Cottonwood Lake will also be reduced through the reduction of the frequency and intensity of the algae blooms that occur in the lake.

Acknowledgements

The cooperation of the following organizations and individuals is gratefully appreciated. The assessment of Cottonwood Lake and its watershed could not have been completed without their assistance.

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Shane Jordan, NRCS

Spink Conservation District

Tina Hansen, Redfield Lake Project Coordinator

Lake Identification and Location

Lake Name: Cottonwood Lake
County: Spink
Range: 65W
Nearest Municipality: Redfield
Longitude: 98 deg. 40 min. 30 sec. W
Primary Tributary: Medicine Creek

State: South Dakota
Township: 115N
Sections: 4-5, 7-9, 17-18
Latitude: 44 deg. 47 min. 18 sec. N
EPA Region: VIII
Receiving Body of Water: Medicine Creek

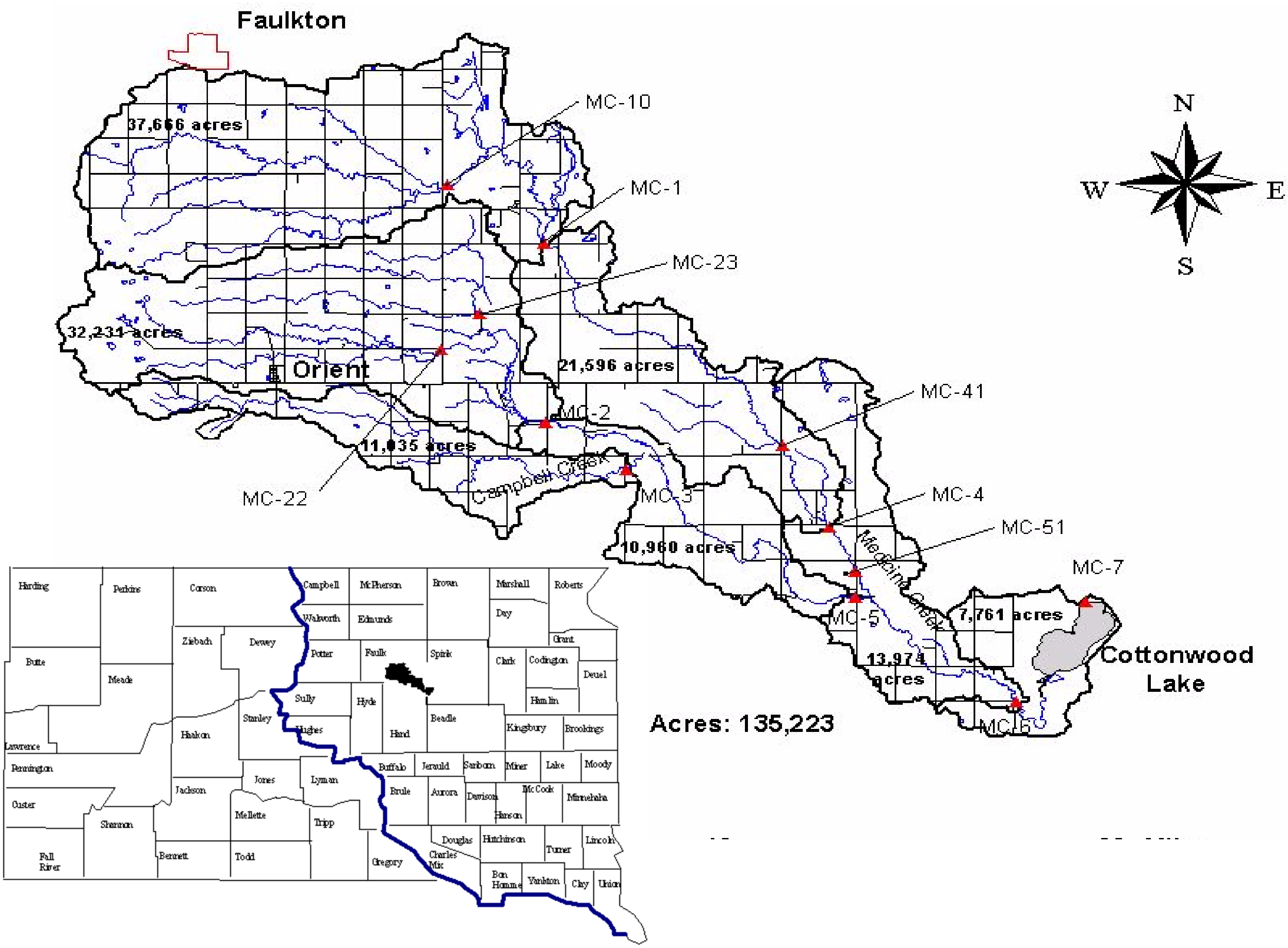


Figure 1. Cottonwood Lake and Medicine Creek Watershed and Tributary Sampling Sites

Abbreviations

AFO	Animal Feeding Operations
AGNPS	Agricultural Non-Point Source Model
BMP	Best Management Practice
CPUE	Catch per Unit Effort
CV	Coefficient of Variance
DC	District Conservationist
DO	Dissolved Oxygen
IJC	International Joint Commission
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Units
PSIAC	Pacific Southwest Interagency Committee Model
Q WTD C	Flow Weighted Concentration
SDDENR	South Dakota Department of Environment and Natural Resources
SDGF&P	South Dakota Department of Game Fish & Parks
SU	Standard Units
TKN	Total Kjeldahl Nitrogen
TSI	Trophic State Index
umhos/cm	microhmos/centimeter
USGS	United States Geologic Survey

Introduction

General Lake Description

Cottonwood Lake is a hypereutrophic lake located in a portion of the James River Basin that lies within Spink County. The lake has an area of 1,649.6 acres (667.6 ha). It reaches a maximum depth of 9.0 feet (2.7 m) and holds a total water volume of 10,722 acre-ft. It is a natural basin, however, the lake outlet has been modified to maintain a more stable lake level as well as a greater volume of water. The only major tributary to the lake is Medicine Creek, which enters on the south end of the lake and flows out through the north end. Due to its shallow nature, the lake is not subject to stratification of any type.

Trophic Status Comparison

The trophic state of a lake is a numerical value that ranks its relative productivity. Developed by Carlson (1977), the Trophic State Index, or TSI, allows a lake's productivity to be easily quantified and compared to other lakes. Higher TSI values correlate with higher levels of primary productivity. A comparison of Cottonwood Lake to other lakes in the area (Table 1) shows that a high rate of productivity is common for the region. The values provided in Table 1 were generated from the statewide lake assessment final report (Stueven, 1996). The TSI for Cottonwood Lake will vary slightly in this report due to the use of more recent data.

Table 1. TSI Comparison for Area Lakes

Lake	Nearest Municipality	TSI	Mean Trophic State
Redfield	Redfield	83.38	Hypereutrophic
Mina	Mina	79.76	Hypereutrophic
Rosette	Ipswich	78.45	Hypereutrophic
Cottonwood	**Redfield**	**76.83**	**Hypereutrophic**
Faulkton	Faulkton	76.32	Hypereutrophic
Louise	Ree Heights	71.16	Hypereutrophic
Bierman Gravel Pit	Chelsea	70.28	Hypereutrophic
Jones	St. Lawrence	68.3	Hypereutrophic
Loyalton Dam	Loyalton	65.28	Hypereutrophic
Richmond	Richmond	60.16	Eutrophic

Beneficial Uses

The State of South Dakota has assigned all of the water bodies that lie within its borders a set of beneficial uses. Along with these assigned uses are sets of standards for the chemical, physical, and biological properties of the lake. These standards must be maintained for the lake to satisfy its assigned beneficial uses. All bodies of water in the state receive the beneficial uses of wildlife propagation and stock watering. Following, is the list of the beneficial uses assigned to Cottonwood Lake, as listed in the state water quality standards:

(6) Warm water marginal fish life propagation
(7) Immersion recreation
(8) Limited contact recreation
(9) Wildlife propagation and stock watering

Recreational Use

The South Dakota Department of Game, Fish, & Parks provides a list of public facilities that are maintained at area lakes (Table 2). Cottonwood Lake has two public boat ramps available for use and each has a boat dock maintained during the summer months. The ramp along the east side of the lake is also equipped with a public toilet. Cottonwood Lake has 141 property owners along its shores and there are approximately 130 cabins that receive use for at least some portion of the year. A growing number of these residents are developing year-round residency at the lake. In addition to those who live or own property around the lake, sportsmen and other recreationists regularly use the lake throughout the year.

Table 2. Comparison of Recreational Uses on Area Lakes

Lake	Parks	Ramps	Boating	Camping	Fishing	Picnicking	Swimming	Nearest Municipality
Redfield	1	1	X	X	X	X	X	Redfield
Mina	1	3	X	X	X	X	X	Mina
Rosette		1	X		X			Ipswich
Cottonwood		**2**	**X**		**X**		**X**	**Redfield**
Faulkton	1	1	X	X	X	X	X	Faulkton
Louise	1	1	X	X	X	X	X	Ree Heights
Bierman Gravel Pit					X			Chelsea
Jones		1	X		X	X		St. Lawrence
Loyalton Dam		1	X		X			Loyalton
Richmond	1	2	X	X	X	X	X	Richmond

Background/History

Geology

Cottonwood Lake and its watershed lie within the James River Basin division of the Central Lowland Physiographic Province. The only major geomorphic feature located in the watershed is the area known as the Orient Hills. They are located at the western end of the watershed and comprise its beginning. Pierre Shale underlies most of the region and has been exposed in areas. Bedrock formations include the Niobrara Formation as well as Carlisle Shale. The area was affected by only one period of glaciation during the late Wisconsin time. Carbon dating estimates that this occurred between 14,000 and 9,000 years ago. Most of the material that overlies the bedrock consists of till and outwash-alluvium mixtures with minor amounts of lacustrine sediments. (Christiansen, 1977)

Population Demographics

There are an estimated 62,644 people living within a 65-mile radius of Cottonwood Lake. The major municipalities included within this region are Aberdeen, Huron, Redfield, Faulkton, and Miller. The primary sources of income are production agriculture and agricultural related businesses. In recent years the area has worked hard to diversify its economy by tapping the available labor market. Today this region is home to companies such as Mutual of Omaha, Trussbilt, and 3M. (Governors Office, Economic Development, 2000). Huron and Aberdeen are to be linked to the nation's interstate highway system over the next few years, encouraging continued growth of these communities.

Water Resources

The groundwater in the Medicine Creek watershed is important for two primary reasons. Approximately 6% of the water entering Cottonwood Lake comes directly from springs. Underlying Cottonwood Lake is the Tulare Aquifer, which has formed in the glacial till. This aquifer has very hard water with calcium as the dominant cation in most samples. It is relatively shallow, typically less than 100 feet, and discharges to the surface in many areas as it flows from western Hand County into eastern Spink County (Koch, 1980).

Due to periods of drought in this region of the state, groundwater is a more reliable source of water for area residents. In addition to the Tulare Aquifer, portions of the Grand, Elm, and other smaller aquifers underlie the area.

Fishery

The most recent fisheries survey was completed July 8-10, 1997. A complete copy of the survey may be found in Appendix A. Species encountered during the survey included yellow perch, walleye, northern pike, black crappie, common carp, and black bullhead. Black bullhead comprised 96% of the total frame net catch. Common carp represented approximately 2.1% of the total catch. Black crappie comprised approximately 0.72% of the total catch. Yellow perch, northern pike, and walleye occurred as 0.41%, 0.31%, and 0.16% of the total catch, respectively.

Black crappie populations have been consistently low since 1990. In 1997, catch per unit effort (CPUE) was the highest at 2.61 with lengths ranging from 19 to 29 cm or 7.5 to 11.5 inches with the majority of the population greater than 22 cm or 8.6 inches. High water levels may have been beneficial to the population. Yellow perch populations ranged from 13 to 31 cm or 5 to 12 inches. Again, high water levels may have contributed to the increased catch of yellow perch. Walleye and northern pike were both found in relatively low abundances. The walleye were 25 to 41 cm or 9 to 16 inches in length. The northern pike were 19 to 77 cm or 7.5 to 30 inches in length.

South Dakota Game, Fish and Parks (SDGF&P) recommend commercial fishing efforts should be encouraged to reduce the black bullhead and common carp populations. The lake should be managed primarily as a walleye and yellow perch fishery with continued walleye stockings and direct habitat development towards these species, if feasible.

Threatened and Endangered Species

There are no threatened or endangered species documented in the Medicine Creek watershed. The US Fish and Wildlife service lists the Whooping crane, Bald eagle, and Western prairie fringed orchid as species that could potentially be found in the area. None of these species was encountered during this study; however, care should be taken when conducting mitigation projects in the Medicine Creek watershed.

Aquatic Macrophyte Survey

The Project Coordinator and SD DENR staff conducted an aquatic plant survey on August 19, 1999. Very little submerged vegetation was observed throughout the lake. Emergent vegetation was abundant along the shoreline. Approximately 50 % of the shore was lined with a variety of species. The identified species and their habitat can be found in the following table.

Table 3. Cottonwood Lake Aquatic Macrophytes

Common Name	Genus	Species	Habitat
Chairmakers Rush	*Scirpus*	*pungenes*	Emergent
Common Reed	*Phragmites*	*australis*	Emergent
Coontail	*Ceratophyllum*	*demersum*	Submergent/ Floating
Cottonwood	*Populus*	*deltoides*	Emergent
Dull-leaf Indigo	*Amorpha*	*fruiticosa*	Emergent
Green Ash	*Fraxinus*	*pennsylvanica*	Emergent
Narrow-Leaved Cattails	*Typha*	*angustifolia*	Emergent
Prairie Cord Grass	*Spartina*	*pectinata*	Emergent
Reed Canarygrass	*Phalaris*	*arundinacea*	Emergent
River Bulrush	*Scirpus*	*fluviatilis*	Emergent
Sago Pondweed	*Potamogeton*	*pectinatus*	Submergent
Sand Bar Willow	*Salix*	*exigua*	Emergent
Smartweed	*Polygonum*	*spp.*	Emergent
Sedge	*Carex*	*spp.*	Emergent
Spikerush	*Elocharis*	*spp.*	Emergent
Strawcolored Nutsedge	*Cyperus*	*strigosus*	Emergent
Swamp Smartweed	*Polygonum*	*coccineum*	Emergent

Very little floating or submergent plant matter was recovered during the aquatic survey. Two samples of coontail were recovered in the bay at the south end of the lake where the inlet for Medicine Creek is located. The only sample that yielded any additional plant matter (sago pondweed) was located at transect 1 (Figure 2). Although only a single sample of sago pondweed was recovered, it was noted that large and somewhat sparse beds of the plants were found along the shore on the northwest side of the lake. Table 4 lists the density rating of each plant species along with the lake depth and Secchi reading at each position. The density was rated according to the number of times that the plant was recovered at each position by means of a plant grapple thrown in four different directions. A density rating of 5 means the species was dense while a 1 indicates that it was present but sparse at that location. Figure 2 contains a map indicating the location of each transect. Sampling position A for each transect was located close to the shore while the position B was located closer to the center of the lake. Transect 22 was the only exception to this with position A located along the west shore of the bay and position B located along the east edge of the bay.

Aquatic plant growth and colonization may be linked to the mean Secchi depth for a lake (Canfield, 1985). Canfield proposed that there is a direct link between the mean depth that plants will colonize in a lake and its Secchi reading. Using data from Wisconsin lakes, he came up with the following relationship where MDC is the maximum depth of colonization and SD is the mean Secchi depth.

Equation 1. Mean Depth Colonization Calculation

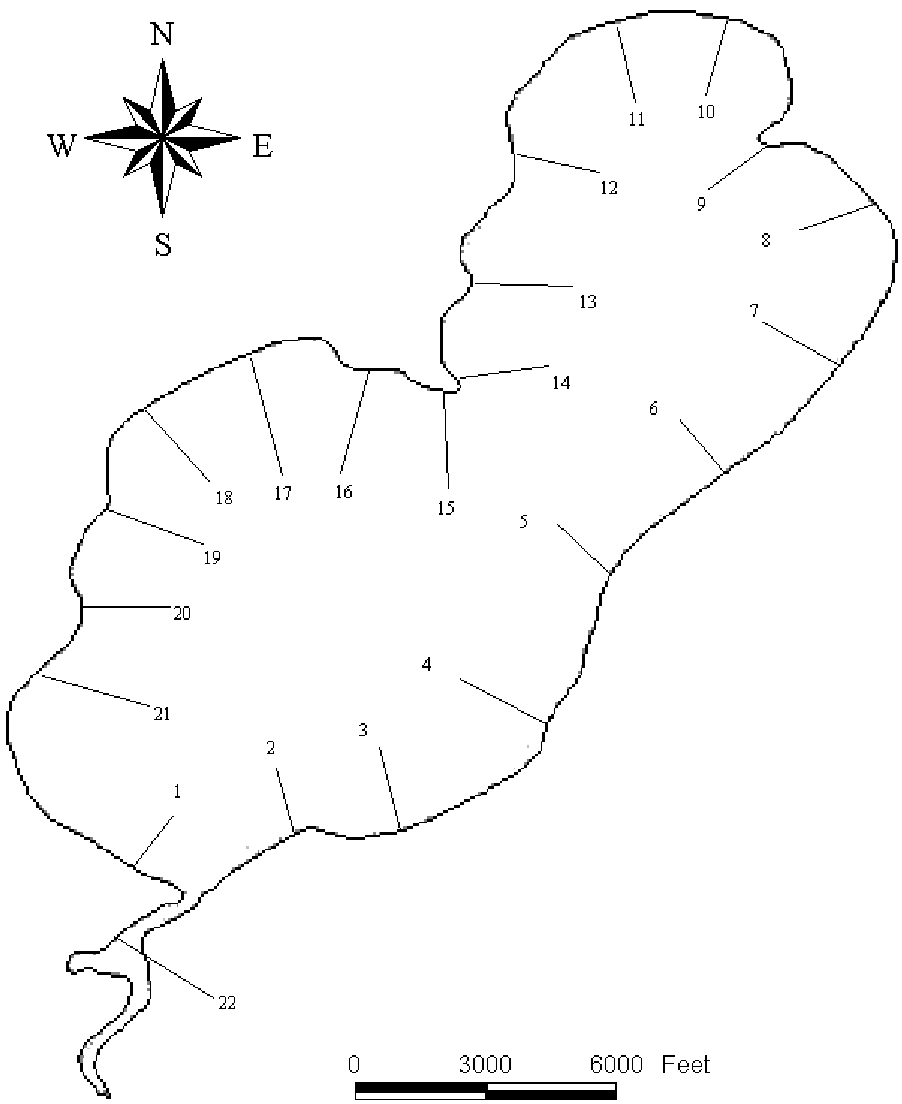
$$\log \; MDC = (.61 \; \log \; SD) + .26$$

When calculated for Cottonwood Lake (mean Secchi = 1.0 m), a depth of 1.8 meters (5.9 feet) was found to be the maximum expected depth for macrophyte colonization.

Table 4. Cottonwood Lake Aquatic Plant Densities

Transect	Position	Secchi (ft)	Depth (ft)	Coontail	Sago Pondweed
1	A	1.5	4	-	-
1	B	1.3	7	-	1
2	A	1.3	4	-	-
2	B	1.3	6	-	-
3	A	1.5	3	-	-
3	B	1.6	5	-	-
4	A	1.6	3	-	-
4	B	1.7	5	-	-
5	A	1.3	4	-	-
5	B	1.8	5	-	-
6	A	0.5	3	-	-
6	B	1	4	-	-
7	A	0.8	4	-	-
7	B	1.3	5	-	-
8	A	1.5	4	-	-
8	B	2	6	-	-
9	A	1.5	4	-	-
9	B	1.6	6	-	-
10	A	1.3	3	-	-
10	B	1.6	6	-	-
11	A	2	3	-	-
11	B	1.9	6	-	-
12	A	1.6	5	-	-
12	B	2	6	-	-
13	A	1.9	4	-	-
13	B	2.2	4	-	-
14	A	2	4	-	-
14	B	1.8	6	-	-
15	A	1.5	4	-	-
15	B	2.2	6	-	-
16	A	1.9	4	-	-
16	B	2	4	-	-
17	A	1.5	4	-	-
17	B	1.7	5	-	-
18	A	1.8	4	-	-
18	B	2	5	-	-
19	A	2.1	4	-	-
19	B	2	5	-	-
20	A	1.8	4	-	-
20	B	2.5	5	-	-
21	A	2	4	-	-
21	B	1.9	6	-	-
22	A	1.4	4	2	-
22	B	1.4	4	-	-

Figure 2. Cottonwood Lake Aquatic Plant Survey Transect Lines



The shoreline around Cottonwood Lake was home to a variety of lakeshore plant species. The shoreline along the inlet at the south end of the lake was lined with cattails. Willows, prairie cord grass, dull leaf indigo, and smartweed were found on the wet ground surrounding the cattails. The riparian area surrounding the remainder of the lake had scattered stands of reed canary grass, prairie cord grass, smartweed, dull leaf indigo, cottonwood trees, and willow trees. Emergent species that grow in the water such as the sedges, bulrushes and cattails were very scarce outside of the inlet. The few stands of these species that were observed were small and sparsely populated. A map located in Figure 3 shows the general location of some of the more prominent species around and within the lake.

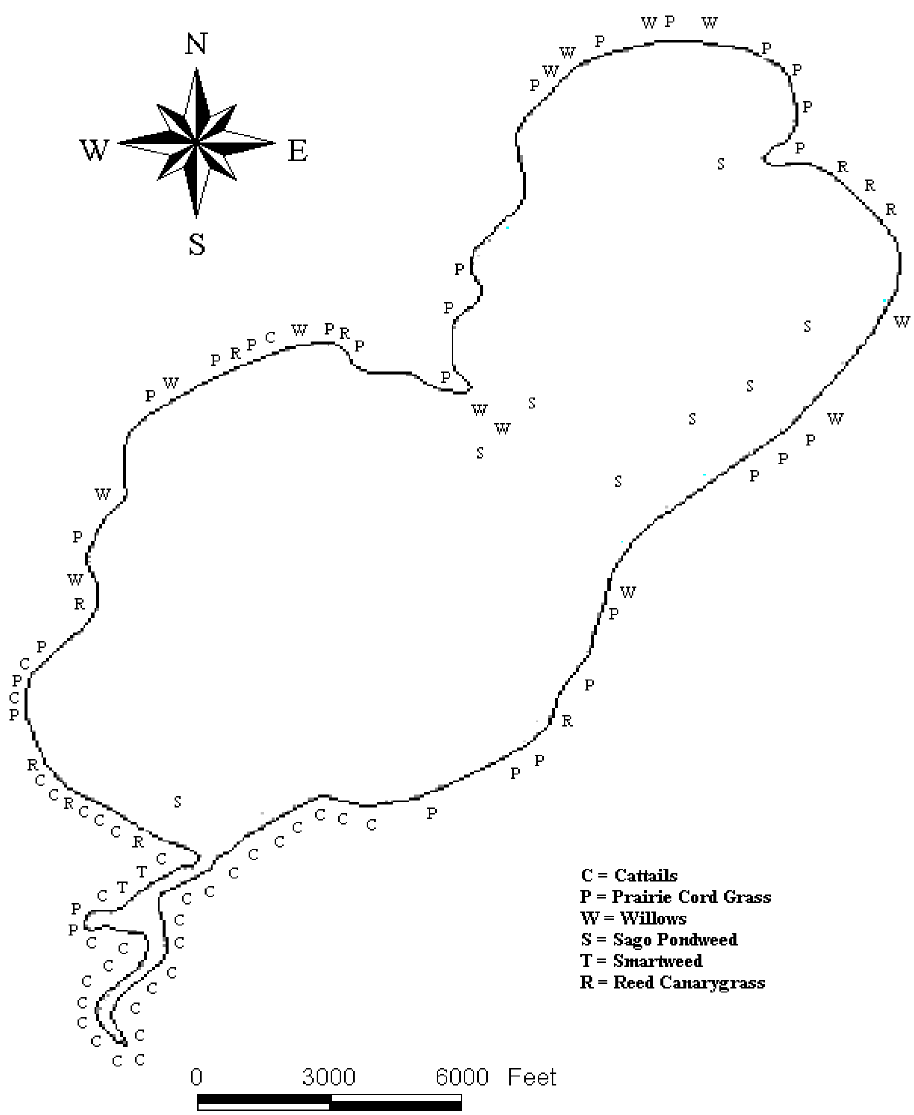


Figure 3. Location of Prominent Aquatic Plant Species in Cottonwood Lake

Septic Survey

A septic survey was conducted at the lake during late fall and early winter. Questionnaires and letters explaining the reason for the survey were mailed to all of the property owners at the lake. Of the 141 property owners, 112 (80%) responded to the mailing. Information requested included the type of wastewater disposal system their cabin was equipped with, fertilizer and pesticide use, presence of artesian wells, and annual usage of their cabin.

The primary focus of the survey was intended to give a general idea of the types of wastewater management systems that are being used around the lake. Table 5 indicates the recurrence of the different systems used. Almost all of the septic systems are less than 200 feet from the lake with some located within 100 feet. Soils for this area include Houdek Loams and Maddock Sandy Loams. The Houdek Soils on the western side of the lake are classified as severely limited for septic suitability due to slow percolation. This portion of the lakeshore is subject to high water tables that may cause failed septic systems to leach to the lake. The eastern side of the lake consists primarily of Maddock soils. These soils are excessively well drained and allow for some leaching of phosphorus to the lake.

Table 5. Frequency of Septic System Types

Outhouse	28%
Septic system draining away from lake	50%
Septic system draining to the lake	3%
Porta Potty	1%
Holding Tank	2%
Other (usually no facilities)	8%
Combination of 2 systems	8%

These onsite wastewater disposal facilities are an important consideration when assessing the nutrient load to the lake. Phosphorus loads from those facilities can and do reach the lake, adding to its nutrient load. A method was developed by Rodiek on Lobdell Lake in Michigan to assess the impact of septic systems on the nutrient loads. Using part time and full time residency as well as loads from Table 6, he was able to develop an annual loading to the lake.

Table 6. Phosphorus Loading Rates, (Copied from Rodiek, 1978)

Assumptions		Lake Residences Loading rates to septic systems
4 people per residence	without detergent	0.50 kg x $capita^{-1}$ x yr^{-1}
50% occupancy of residences	detergent only	1.60 kg x $capita^{-1}$ x yr^{-1}
50% use of phosphorus detergent	detergent only	1.10 kg x $capita^{-1}$ x yr^{-1}

Equation 2. Phosphorus Export for Permanent Residence:

$$\left[\left(0.5\frac{\text{kg - P}}{\text{capita - yr}}\times\frac{\text{4 capita}}{\text{residence}}\right)+\left(1.1\frac{\text{kg - P}}{\text{capita - yr}}\times\frac{\text{4 capita}}{\text{residence}}\times 0.50\ \text{P detergent}\right)\right]=4.2\frac{\text{kg - P}}{\text{residence - yr}}$$

Equation 3. Phosphorus Export for Temporary Residence (assumed 50% of year occupancy):

$$\left[\left(0.5\frac{\text{kg - P}}{\text{capita - yr}}\times\frac{\text{4 capita}}{\text{residence}}\right)+\left(1.1\frac{\text{kg - P}}{\text{capita - yr}}\times\frac{\text{4 capita}}{\text{residence}}\times 0.50\text{P detergent}\right)\right]\times 0.5\,\text{occupancy}=2.1\frac{\text{kg - P}}{\text{residence - yr}}$$

Using these estimates for phosphorus contributions to the septic system from each permanent and temporary residence on Cottonwood Lake, a total contribution can be calculated:

$$4.2\frac{\text{kg - P}}{\text{residence}}\times 17\ \text{permanent residence}=71.4\ \text{kg - P}$$

$$2.1\frac{\text{kg - P}}{\text{residence}}\times 112\ \text{seasonal residence}=235.2\ \text{kg - P}$$

These calculations combine for a total of 306.6 kg of phosphorus that could be delivered to the septic systems around the lake. Rodiek found phosphorus retention in the soil to range from 25% to 75%. This would yield from 76.7 kg to 230 kg of delivered phosphorus to Cottonwood Lake. Taking into consideration the high levels of caffeine that were measured in the lake (discussion on page 71); the large increase in nitrates that occurred during mid-summer; as well as the leaching potential of some of the soil; a conservative estimate of 65% of the phosphorus load could be assumed to be reaching the lake on an annual basis (199.3 kg). Septic leachate accounts for 4% of the total phosphorus load to Cottonwood Lake.

Cabin and lake use were also addressed in the survey. Table 7 indicates the amount of time that the cabins and lake are used each year.

Table 7. Lake Residence Use

Never used	9%
30 days or less	43%
31 to 180 days	31%
181 to 210 days	5%
Permanent	12%

The final issues that the survey addressed were the use of pesticides, fertilizers, and the presence of flowing or artesian wells. Some type of pesticide use during the year was indicated by 20% of the respondents. This varied from weed killers to insect repellents for grass and garden crops. Fertilizer use was reported by 28% of the respondents with the majority applying nitrogen at various rates. Individuals reporting flowing wells were contacted and the amount of water discharging into the lake was calculated. Random samples of the various wells were also collected to determine the impact that they have on the lake.

PSIAC

The Pacific Southwest Inter-Agency Committee (PSIAC) model is an assessment tool designed to determine sediment loadings in large watersheds that are greater than 50% grass and rangeland. The model is based on characteristics such as land use, cropping practices, soil types, local climate, and stream characteristics. The evaluation is done using a multidisciplinary team consisting of local and regional NRCS personnel, staff from Water Resource Assistance Program, and local coordinators. NRCS personnel in the South Dakota State Office then generate the report. The complete PSIAC report may be found in Appendix B.

PSIAC bases reduction estimates on expected participation rates of BMP application. These rates are broken down into three classes for Low, Moderate, or High involvement. Low participation rates expect Best Management Practices (BMP) on 20% of the rangeland and 10% of the cropland. Moderate participation is based on 30% for rangelands and 15% for croplands. High participation is based on 40% for rangeland and 20% for cropland. These percentages are based on the improvement of range condition by a factor of one class such as fair to good. Cropland percentages are based on improving crop residue as well as the addition of buffer strips and other BMPs. Table 8 indicates the number of acres that could be expected to be involved in BMPs to reach the participation rates. The acre totals in the PSIAC report were generated by the NRCS and are not equal to those used in the rest of the report. The primary cause for this is the uncertainty of the exact boundary of the watershed, particularly in areas with very little slope.

Table 8. Acres in BMP to Achieve Participation Rates

Land Use	Acres	Acres in BMP		
		Low	Moderate	High
Range	80,707	16,141	24,212	32,283
Cropland	52,703	5,270	7,905	10,541
Hay/Crop	24,773	0	0	0
Other	3,230	0	0	0
Total Acres	161,413	21,412	32,118	42,823

PSIAC deals exclusively with sediment (suspended solids loads) but phosphorus loads may be linked to these loads. Phosphorus loads may be found in two primary forms, attached and dissolved. Attached loads are calculated by subtracting the dissolved portion of the load from the total load. The loads used in equation 4 were generated by the FLUX program and will be addressed later in this report.

Equation 4. Attached Phosphorus Calculation

Total Phosphorus – Dissolved Phosphorus = Attached Phosphorus

5894 kg – 3468 kg = *2426 kg of Attached Phosphorus*

Medicine Creek delivers a total load of 5,894 kg of phosphorus to Cottonwood Lake annually. Of this, 2426 kg (41%) is attached to suspended solids. The annual suspended solids load is 979,173 kg. Attached phosphorus (AP) loads were linked to total suspended sediment (TSS) loads on Lake Lanier in Georgia and on the Chattahoochee River (Rasmussen, 2000). Loading ratios of AP: TSS for Lake Lanier in Georgia ranged from .0025 to as high as .009, while the Chattahoochee River had a value of .004. The attached phosphorus to total suspended sediment ratio for Cottonwood Lake is a conservative AP=.002 TSS.

Equation 5. Attached Phosphorus Ratio

$$\frac{TotalAttachedPhosphorous}{TotalSuspendedSolids} = \frac{2426Kg}{979{,}173Kg} = .002$$

As proposed by Rasmussen, reducing the suspended solids load will reduce the attached phosphorus load by an equal percentage. The total phosphorus load will be reduced by a smaller percentage because the sediment reduction will not affect the dissolved portion of the load. When this ratio is used with the reduced solids loads predicted by PSIAC, reduction estimates can be calculated. Table 9 indicates the phosphorus reductions that can be expected when the participation rates are met. Solids reductions vary from 4.3% to 7.6% for the highest participation rate. Phosphorus reductions from rangeland and cropland BMPs ranged from 1.8% to 3.1%.

Table 9. Expected Suspended Solids and Phosphorus Reductions from PSIAC

Participation Rate	Low	Moderate	High
% Suspended Solids Reduction	4.3%	5.6%	7.6%
Annual Suspended Solids Load	979,173	979,173	979,173
Predicted Suspended Solids with Reduction	937,069	924,339	904,756
Ratio Attached Phosphorus: Suspended Solids	0.002	0.002	0.002
Annual Phosphorus Load	5,894	5,894	5,894
Predicted Attached Phosphorus after Reduction	2,322	2,290	2,242
Predicted Total Phosphorus after Reduction	5,790	5,758	5,710
% Total Phosphorus Reduction	1.8%	2.3%	3.1%

AGNPS

To uniformly assess the impact of the animal feeding operations located within the watershed, the Agricultural Non-Point Source (AGNPS) feedlot assessment subroutine was employed. A complete evaluation was conducted on all animal-feeding areas with a defined drainage to Medicine Creek. Lots with drainage confined to a small area with no defined discharge were not rated during the assessment because they had little or no impact. Lots that were rated were assessed for a 25-year, 24-hour storm event in the drainage area. This is the largest event that waste systems in the area are designed to handle.

The Cottonwood Lake and Medicine Creek drainage area consists of a very high percentage of range and pastureland (86%) mixed with cropland (12%). Due to the high percentage of grassland, an AGNPS model was not completed on the entire watershed. The PSIAC model was used to assess rangeland and cropland conditions and estimate sediment delivery rates. The subwatersheds contain a large number of animal feeding operations (AFOs) that PSIAC is not capable of assessing. The AGNPS Animal Feeding Operation Subroutine was used to assess each of those areas. Each feedlot was numbered, linked to a subwatershed, and then assessed to obtain an AGNPS ranking number. AGNPS ranks feedlots from 0 to 100 for a 25-year, 24-hour storm event simulation, which is the equivalent of a 4.1-inch rainfall event for this area. A ranking of zero equals no expected water quality impacts, increasing numbers are not necessarily linked to a nutrient load, however higher rankings would be expected to have a greater impact on the water quality. The 25-year, 24 hour event was selected because it is used as the design event for constructing animal waste systems in the area.

There were 61 feeding areas identified during a visual survey conducted during the summer of 1999. Many of the lots targeted for assessment were used for only a small portion of the year, often as holding lots for calves prior to sale. Of the 61 feeding areas, the AFO subroutine was completed on 60. One lot was under expansion and no data was accessible for it. Twenty-seven lots received a rating of 0 for a variety of reasons; some were no longer being used, some did not receive enough use to rate them, and in a few instances the lots were in a closed drainage system with no discharge to the stream system. The remaining lots received rankings from 12 to 92. Table 10 indicates the predicted phosphorus loads originating from AFOs that could be expected to discharge from each of the subwatersheds as a result of a 4.1-inch rainfall event. Table 10 also indicates the total annual phosphorus discharge that occurs from each of these subwatersheds.

Table 10. Calculated and AGNPS Predicted Phosphorus Loads to Cottonwood Lake

Sub-Watershed	AGNPS Predicted Phosphorus Loads for Design Event (kg)	Calculated Total Annual Phosphorus Loads (kg)
MC-1	597	1637
MC-2	163	2121
MC-3	47	171
MC-4	717	1544
MC-5	285	1459
MC-6	1061	5894

Data obtained from a 1.25-inch rainfall event, which occurred during late April of 2000, allowed for a comparison between AGNPS-predicted loads and actual loads, using the AGNPS feedlot subroutine to simulate a 1.25-inch rainfall. The model predicted that 160 kg of phosphorus would be delivered to Cottonwood Lake from the AFOs. Calculated loads for this storm event were 406 kg of total phosphorus delivered to the lake. Comparing the two loads would indicate that approximately 39% of the total P load to the watershed was the direct result of AFO discharge. The 20 AFOs that ranked at 34 or greater represented 34% of the phosphorus load to Cottonwood Lake. These lots were selected because each one contributed over 1% of the AFO portion of the phosphorus load. Considering the annual load to Cottonwood Lake, the highest-ranking AFO (92) contributed 16% while the remaining 19 AFOs individually contributed approximately 1% of the load.

The phosphorus load may be substantially reduced in the future by the removal of one of the AFOs from subwatershed MC-1. This particular AFO rated at 92 and contributed over 42% of the AGNPS total predicted phosphorus load. This feeding operation is currently under the permitting process and will have a waste management system installed. Subwatershed MC-1 also had an additional lot under construction but no rating information was available for it. The phosphorus load for the AFOs located above each of the monitoring sites is listed in Table 10. Individual AFO data is available in Appendix B.

Sediment Survey

The amount of soft sediment on the bottom of a lake may be used as an indicator of the volume of erosion occurring in its watershed and along its shoreline. The soft sediment on the bottom of lakes is often rich in phosphorus. Due to Cottonwood Lake's shallow nature, wind induced wave action agitates the bottom of the lake bringing those sediments and nutrients into the water column. The accumulation of sediments in the bottom of lakes may also have a negative impact on fish and aquatic invertebrates. Sediment accumulation may often cover bottom habitat used by these species. The end result may be a reduction in the diversity of aquatic insect, snail, and crustacean species.

The sediment survey on Cottonwood Lake was conducted during May of 2000. While normally conducted during a period of ice cover, the warm winter of 1999-2000 resulted in its completion from a boat. Along with water and sediment depths, an elutriate sample was collected from the lake for pesticide analysis.

Cottonwood Lake has an estimated sediment volume of 4,799,050 m3. A majority of this volume is found throughout the center of the lake. Most of the lake has 1 meter of sediment with approximately 3 meters of water over it. A bathymetric map of the sediment in Cottonwood Lake can be found in Figure 4. In many cases there was little or no sediment accumulation near the shoreline where water depths were substantially less than in the center of the lake. This is most likely due to the wind driven turbidity in the lake, the shallow water along the edges is agitated more often moving the sediment to the center of the lake where it is able to settle back to the bottom.

Elutriate samples were collected with a Petite Ponar and shipped to the State Health Lab for analysis. In addition to sediment, a volume of 3 gallons of water was collected at each of the testing sites as well and was analyzed for the same chemicals as the sediment. The results of the elutriate test completed on the lake were all below the detection limit with the exception of lead, which was found at a concentration of 0.1 ppb. Table 11 indicates the various toxins that were tested for in the elutriate sample.

Table 11. Toxins that were Screened for in the Elutriate Test at Cottonwood Lake

Elutriate Test Toxins (none detected)	
ALACHLOR	DIAZINON
CHLORDANE	DDD
ENDRIN	DDT
HEPTACHLOR	DDE
HEPTACHLOR EPOXIDE	BETA BHC
TOXAPHENE	HAMMA BHC
ALDRIN	ALPHA BHC
DIEDRIN	MERCURY
PCB	LEAD

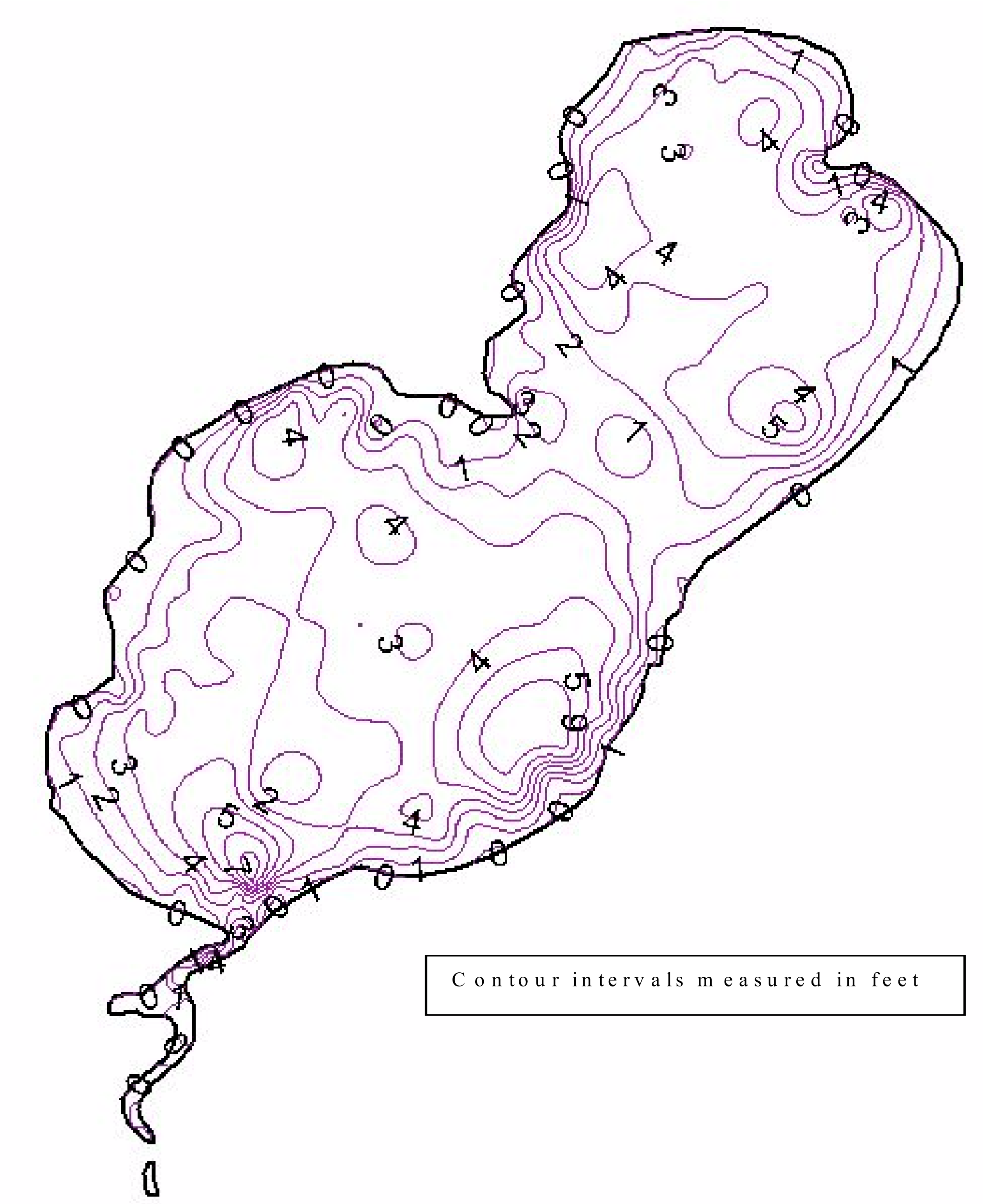


Figure 4. Cottonwood Lake Sediment Map

Quality Assurance/ Quality Control (QA/QC)

Quality Assurance/ Quality Control (QA/QC) samples were collected for 10% of the inlake and tributary samples taken. A total of 30 lake samples were collected along with three sets of duplicates and blanks. The 43 tributary samples had six pairs of duplicates and blanks collected with them. Complete test results for duplicates and blanks may be found in the following figures (blank samples with detectable levels of nutrients are highlighted).

Blank inlake samples yielded undetectable levels of all nutrients and solids with the exception of the total solids. Total solids were detected in all three of the blank samples that were placed with the lake samples. This may be the result of contaminated distilled water or poorly rinsed sample bottles.

Inlake duplicate samples consistently produced differences of less than 10 % for most parameters. Suspended and volatile solids had large differences (>25%) on several occasions. However, data pairs that were often 1 or 2 mg/L different often produced these large percentages. This is primarily due to the low concentrations found in the samples.

Tributary samples had several parameters in which detectable levels of nutrients were obtained from blank samples. Two instances of dissolved phosphorus without detectable total phosphorus in the blanks may be directly attributed to inadequate rinsing of the filtering apparatus. Two detections of total solids as well as one instance of suspended solids were also obtained from blank samples. Total solids might be attributed to low-grade distilled water. There was also one blank sample that had a level of nitrate at the detection limit.

Duplicates for the tributary samples produced consistently lower percent differences than the inlake samples. Higher percent differences were indicated in the same parameters as the inlake samples, that is with volatile and suspended solids. Low concentrations were again responsible for the larger percent differences.

SITE	DATE	Sample Type	Total Alkalinity	Total Solids	Total Dissolved Solids	Total Suspended Solids	Ammonia	Nitrate	TKN	Total Phosphorus	Total Dissolved Phosphorus	Fecal Coliforms	Total Volatile Suspended Solids
MC-9	06/08/1999	BLANK	<7	<5	<5	<1	<0.02	<0.1	<0.14	<0.002	0.01		
MC-11	06/08/1999	DUPLICATE	310	1576	1486	19	0.01	0.05	3.15	1.04	0.898		
MC-1	06/08/1999	GRAB	312	1591	1497	23	0.01	0.05	3.10	1.01	0.927		
% Difference			1%	1%	1%	19%	0%	0%	2%	3%	3%		
MC-9	06/29/1999	BLANK	<7	<5	<4	<1	<.02	<.1	<.14	<.002	<.002	<10	
MC-12	06/29/1999	DUPLICATE	398	1365	1294	22	0.01	.1	1.9	.951	.874	770	
MC-2	06/29/1999	GRAB	395	1391	1269	36	0.01	.1	1.88	.952	.843	740	
% Difference			1%	2%	2%	48%	0%	0%	1%	0%	4%	4%	
MC-9	11/16/1999	BLANK	<7	9	<4	<1	<.02	0.1	<.14	<.002	<.002	<10	
MC-12	11/16/1999	DUPLICATE	411	1609	1528	13	0.01	0.05	0.55	0.092	0.056	10	1
MC-2	11/16/1999	GRAB	401	1614	1533	10	0.01	0.05	0.56	0.097	0.057	10	1
% Difference			2%	0%	0%	26%	0%	0%	2%	5%	2%	0%	0%
MC-9	05/04/2000	BLANK	<7	<5	<4	<1	<.02	<.1	<.14	<.002	<.002	<10	
MC-17	05/04/2000	DUPLICATE	334	1504	1430	26	0.3	0.1	2.33	0.248	0.182	60	5
MC-7	05/04/2000	GRAB	333	1504	1432	19	0.32	0.1	1.77	0.241	0.160	60	1
% Difference			0%	0%	0%	31%	6%	0%	27%	3%	13%	0%	133%
MC-9	04/27/2000	BLANK	<7	9	<4	1	<.02	<.1	<.14	<.002	<.002	<10	
MC-14	04/27/2000	DUPLICATE	409	3411	3122	78	0.01	0.05	3.56	0.363	0.108	2600	22
MC-4	04/27/2000	GRAB	412	3417	3184	76	0.01	0.05	3.45	0.366	0.111	3000	22
% Difference			1%	0%	2%	3%	0%	0%	3%	1%	3%	14%	0%
MC-9	03/07/2000	BLANK	<7	<5	<4	<1	<.02	<.1	<.14	<.002	0.002	<10	<1
MC-15	03/07/2000	DUPLICATE	308	1540	1459	12	0.03	0.05	1.79	0.451	0.330	110	5
MC-5	03/07/2000	GRAB	313	1538	1467	7	0.02	0.1	1.66	0.437	0.337	90	3
% Difference			2%	0%	1%	53%	40%	67%	8%	3%	2%	20%	50%
Max Error for Duplicates			2%	2%	2%	53%	40%	67%	27%	5%	13%	20%	133%
Standard Error for Duplicates			1%	1%	1%	30%	8%	11%	7%	3%	4%	8%	46%
Maximum Value for Blanks			0	9	0	1	0	0.1	0.00	0.000	0.01	0	0

Figure 5. QA/QC Data

SITE	DATE	Sample Type	Total Alkalinity	Total Solids	Total Dissolved Solids	Total Suspended Solids	Ammonia	Nitrate	TKN	Total Phosphorus	Total Dissolved Phosphorus	Fecal Coliforms	Total Volatile Suspended Solids
CL-9	10/26/1999	BLANK	<7	<5	13	<1	<.02	<.1	<.14	<.0002	<.0002	<10	<1
CL-11	10/26/1999	DUPLICATE	320	1427	1385	7	0.04	0.1	1.55	0.219	0.185	5	6
CL-1	10/26/1999	GRAB	319	1425	1391	3	0.02	0.1	1.75	0.206	0.173	10	1
% Difference			0%	0%	0%	80%	67%	0%	12%	6%	7%	67%	143%
CL-9	02/16/2000	BLANK	<7	<5	4	<1	<.02	<.1	<.14	<.002	<.002	<10	<1
CL-13	02/16/2000	DUPLICATE	334	1626	1573	3	0.01	0.05	1.59	0.248	0.204	1	3
CL-3	02/16/2000	GRAB	335	1631	1568	2	0.01	0.05	1.48	0.226	0.218	1	1
% Difference			0%	0%	0%	40%	0%	0%	7%	9%	7%	0%	100%
CL-9	03/23/2000	BLANK	<7	<5	10	<1	<.02	<.1	<.14	<.0002	<.0002	<10	<1
CL-11	03/23/2000	DUPLICATE	311	1449	1384	20	0.03	0.1	1.90	0.282	0.200	5	5
CL-1	03/23/2000	GRAB	310	1443	1376	19	0.03	0.1	1.91	0.282	0.199	5	4
% Difference			0%	0%	1%	5%	0%	0%	1%	0%	1%	0%	22%
Max Error for Duplicates			0%	0%	1%	80%	67%	0%	12%	9%	7%	67%	143%
Standard Error for Duplicates			0%	0%	0%	42%	22%	0%	7%	5%	5%	22%	88%
Maximum Value for Blanks			0	0	13	0	0	0	0	0	0	0	0

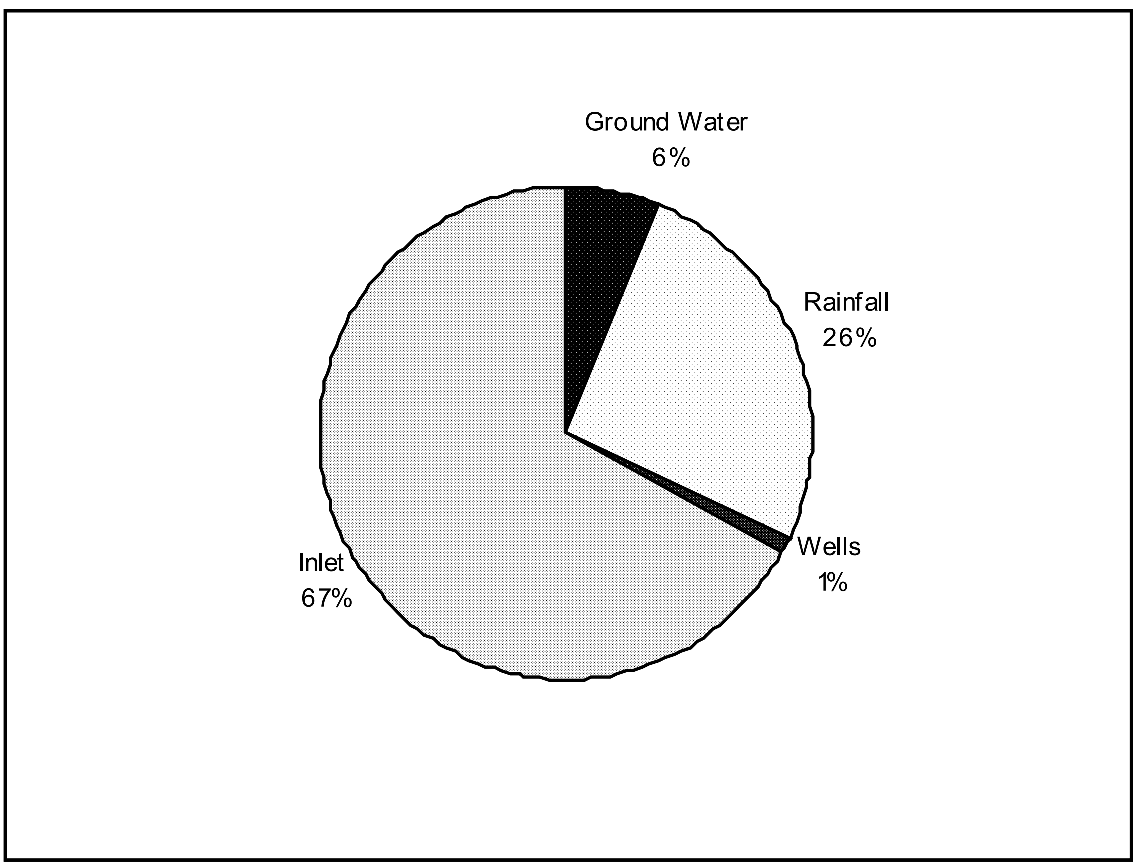
Figure 6. QA/QC Data

Hydrologic Data

Project Hydrologic Loading Budget

There are several sources of water to Cottonwood Lake, of which the primary source is Medicine Creek. The water budget in Figure 5 represents the total hydrologic loadings that occurred to the lake during the project. The sum of all of the inputs yields 13,952,000 cubic meters of runoff or 11,000 acre-feet. Rainfall totals were kept at the inlet to the lake and were approximately 21.35 inches. All of the flowing wells along the lake were measured, and comprised about 1% of the total hydrologic budget for the lake. In order to simplify loading calculations, the flowing wells will be included in the groundwater. A gauging station was maintained at the inlet to the lake to determine its contribution to the budget, which amounted to 9.5 million m^3. To determine the amount of groundwater entering the lake, an estimate of evaporation and stream gauging data from the outlet were totaled. The difference is reflected as the 6% represented by the groundwater portion of the graph.

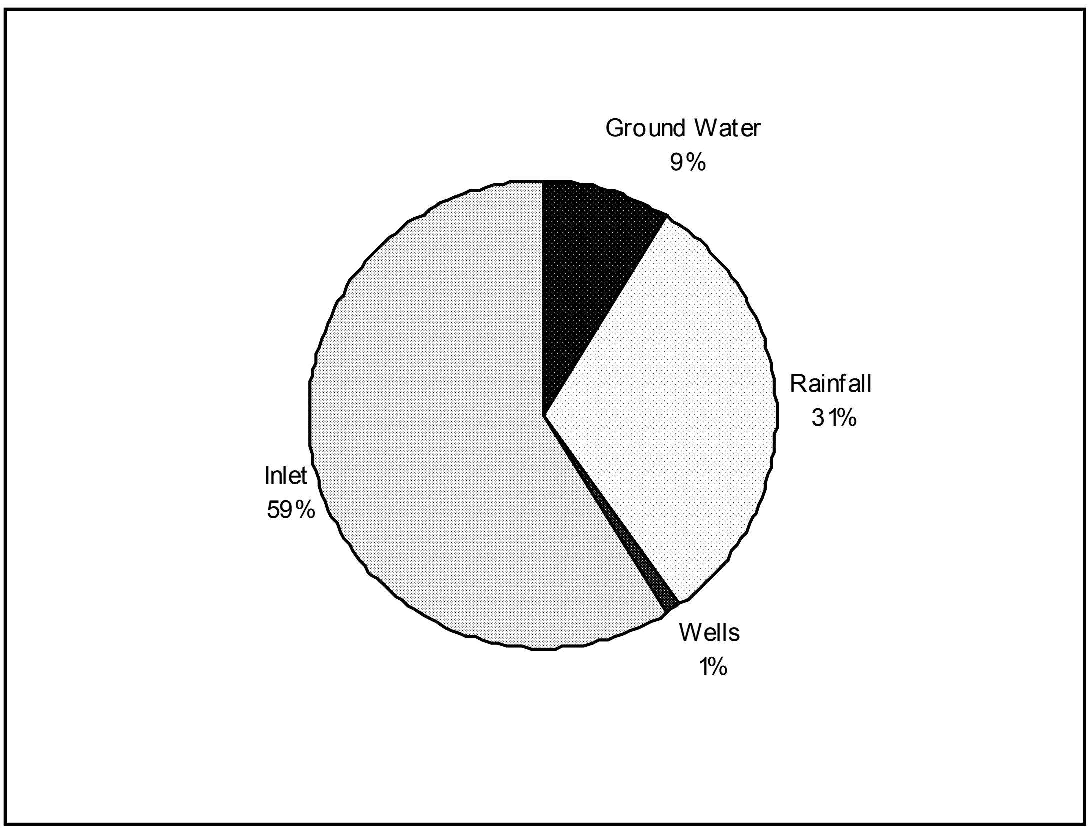
Figure 7. Project Hydrologic Loading Budget for Cottonwood Lake



Annual Hydrologic Loading Budget

The Annual Hydrologic Budget (Figure 6) represents the hydrologic budget of Cottonwood Lake for a typical year. Data from the United States Geologic Service (USGS), which maintained a gauging station at site MC-6 (inlet to the lake) for a period of 30 years, was used to determine the average annual flow of the stream at the inlet to the lake. USGS estimates that in an average year Medicine Creek contributes approximately 4,590 acre-feet of water to the lake. The average annual precipitation at Cottonwood Lake is approximately 18 inches. Taking into account these two factors as well as estimating that the groundwater and well contributions remain relatively constant, the following representation of Cottonwood Lake's average annual hydrologic budget was produced. In a typical year, Medicine Creek accounts for 59% of the water entering the lake. For calculation of loadings for this report, the water budget for the project period was used due to the lack of USGS data for the other sites in the watershed.

Figure 8. Annual Hydrologic Loading Budget for Cottonwood Lake



Nutrient and Sediment Budgets

As streams and rivers pass through lakes, ponds, and other impoundments, they may lose or accumulate nutrients and sediments. Medicine Creek exhibits a loss of some nutrients as it passes through the lake. It loses approximately 50% of its total phosphorus load and 60% of the dissolved phosphorus portion of the load. It also appears to lose approximately 10% of its organic nitrogen.

Nitrates/ nitrites and ammonia increased as Medicine Creek passed through Cottonwood Lake. This increase may be linked to the decrease in organic nitrogen. The most likely source of the increased nitrates and ammonia is the breakdown of organic forms of nitrogen into inorganic forms.

A loss of sediment is expected as a stream passes through a lake. In the case of Cottonwood Lake this does not happen. The lake is large, yet so shallow that wind induced wave action prevents many of the suspended sediments from settling out of the water column. The sediments that do settle out are easily resuspended. In the case of Cottonwood Lake more sediment actually left the lake than accumulated in it during the project. Approximately 243 tons more, which is a 30% increase over the sediment load to the lake. The most likely source for this sediment is the cutbank shoreline along the eastern and southeastern sides of the lake.

Table 12. Nutrient and Sediment Budgets

	Units	Inlet	Outlet	Difference
Total Phosphorus	**kg**	**5894.1**	**2901.6**	**-2993**
Total Dissolved Phosphorus	**kg**	**3467.7**	**1385.8**	**-2082**
Total Alkalinity	Tons	3654.0	4193.7	539
Total Solids	Tons	16908.0	17616.4	708
Total Dissolved Solids	Tons	14534.0	16238.0	1704
Total Suspended Solids	Tons	836.0	1079.4	243
Ammonia	kg	119.1	1406.5	1287
Nitrate/ Nitrite	kg	593.9	2642.9	2049
Total Nitrogen	kg	22949.0	23867.1	918
Organic Nitrogen	**kg**	**22235.9**	**19817.8**	**-2418**
Inorganic Nitrogen	kg	713.0	4049.3	3336

Tributary Water Quality

The state of South Dakota assigns a set of beneficial uses to all bodies of water in the state. There are a total of eleven beneficial use classifications. Uses nine and ten, fish and wildlife propagation, recreation, and stock watering and irrigation are assigned to all streams and rivers. There are five water quality criteria that must be maintained to remain in compliance with these standards. Table 13 indicates the eight standards as well as the water quality values that must be maintained for each one.

Table 13. State Water Quality Standards

Nitrate	<50 mg/L (mean) <88 mg/L (single sample)
Alkalinity	<750 mg/L (mean) <1,313 mg/L (single sample)
pH	< 6.5 and <9.5 su
Total Dissolved Solids	<2,500 mg/L for a 30 day geometric mean < 4375 mg/L daily maximum for a Grab Sample
Total Petroleum Hydrocarbon	Less than or equal to 10 mg/L
Oil and Grease	Less than or equal to 10 mg/L
Sodium Adsorption Ratio	Less than or equal to 10 mg/L
Conductivity	<4,000 umohs(mean) <7,000 umohs (single sample

Subwatersheds

Water quality test results indicated that the levels required for nitrate, alkalinity, pH, and conductivity were met at all times. No exceedences were recorded during the project, however very high total dissolved solids levels ranging from 2582 to 3184, which occurred from March 9 through April 27, 2000, were recorded. These levels may have occurred as a result of discharge from a spring a short distance upstream from the sites. The Tulare Aquifer underlies this area and is located fairly shallow in the glacial till. This aquifer has been found (when tested) to have total dissolved solids levels in excess of 4000 mg/L. (Hamilton and Howells, 1996).

The Cottonwood Lake watershed was divided into seven subwatersheds. Figure 7 depicts the percentage of land area that each subwatershed occupies in the Medicine Creek drainage. Six of these compose the Medicine Creek drainage while the seventh consists of the area surrounding the lake. Figure 8 indicates the flow path that nutrients, sediment and water take as they move through the watershed. Drainage MC-1 flows into subwatershed MC-4, which ultimately discharges into subwatershed MC-6. Subwatershed MC-5 receives loadings from MC-2 as well as MC-3 and discharges into

MC-6. Subwatershed MC-7 consists of Cottonwood Lake as well as the land area immediately surrounding the lake.

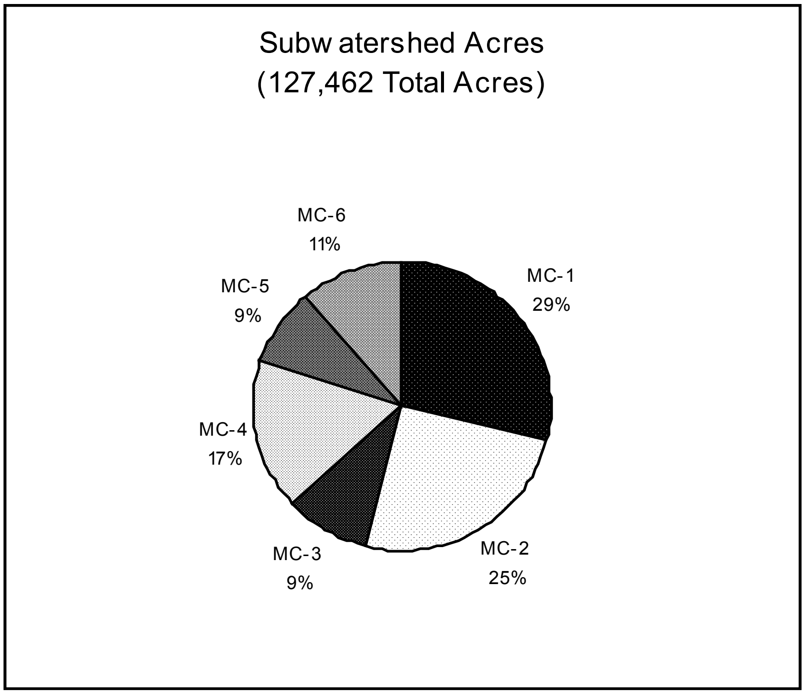


Figure 9. Subwatershed Acres in Medicine Creek

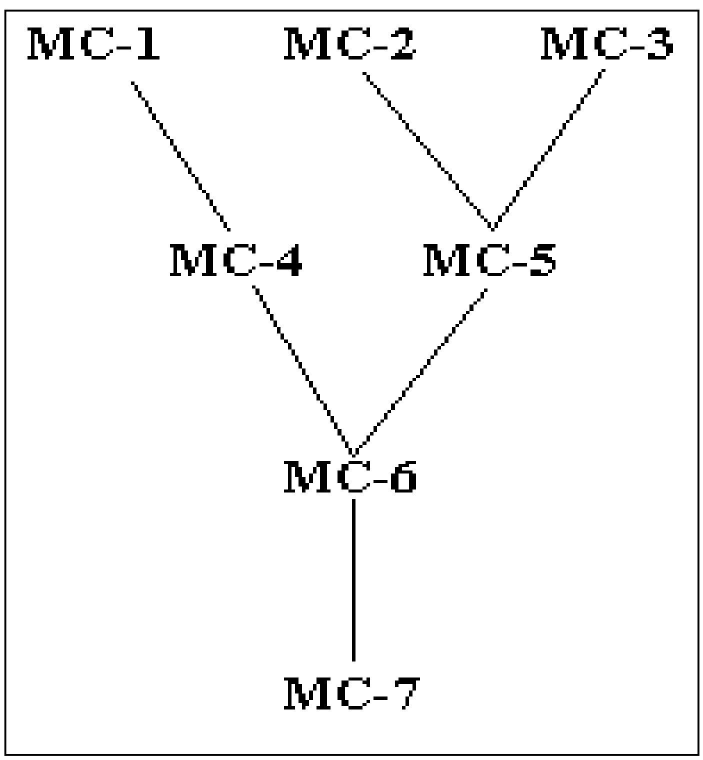


Figure 10. Subwatershed Flow Diagram for Medicine Creek

To calculate the nutrients and sediment that each subwatershed produced, it was necessary to subtract the load entering each subwatershed from the load discharging from it. To exemplify this, the total phosphorus load is calculated in Equation 6. The measured phosphorus load at site MC-6 was 5894 kg. Incoming loads from subwatersheds MC-4 and MC-5 were 1544 kg and 1459 kg respectively.

Equation 6. Subwatershed Loading

[MC-6] – ([MC-5]+[MC-4])= [MC-6] Subwatershed Load

5,894 kg – (1,544 kg + 1,459 kg) = 2,891 kg

This would indicate that a total of 2,891 kg of phosphorus was added to Medicine Creek as a direct result of subwatershed MC-6. In some instances a negative subwatershed load is obtained. This indicates that processes occurring in the stream within that subwatershed were able to consume or restrict the transport of some nutrients and sediments. This was often true when comparing the load entering Cottonwood Lake (MC-6) to the load leaving the lake (MC-7). Medicine Creek flows through various small ponds, stock dams, and marshes as it travels to Cottonwood Lake. They may account for a majority of the reductions occurring in the tributary system. The lake was also acting as a nutrient and sediment sink.

Tributary Water Quality Methods

Flow Calculations

A total of seven tributary monitoring sites were selected along Medicine Creek, the primary tributary to Cottonwood Lake. The sites were selected to determine which portions of the watershed were contributing the greatest amount of nutrient and sediment load to the lake. Four of the sites were equipped with Stevens Type F stage recorders. The remaining three sites were equipped with ISCO flow meters attached to a GLS auto-sampling unit. Water stages were monitored and recorded to the nearest 1/100th of a foot for each of the seven sites. A March-McBirney Model 210D flow meter was used to determine flows at various stages. The stages and flows were then used to create a stage/discharge table for each site. Daily discharge tables may be found in Appendix F, while stage-to-discharge tables are located in Appendix E.

Load Calculations

Total nutrient and sediment loads were calculated with the use of the Army Corps of Engineers Eutrophication Model known as FLUX. FLUX uses individual sample data in correlation with daily discharges to develop six loading calculations. As recommended in the FLUX application sequence, a stratification scheme and method of calculation was determined using the total phosphorus load. Stratification schemes were based on seasonal data, which analyzed spring data separately from flows occurring the rest of the year. This method of calculation was then used for each of the additional parameters. Exceptions for this were volatile total suspended solids and, in some cases, fecal counts. This was due to insufficient data to use the stratification scheme and in some cases to complete the model. For the calculation of this information, a flow-weighted load was estimated. A complete list of all tributary sample data is located in Appendix G.

Tributary Sampling Schedule

Samples were collected from the sites during the spring of 1999 through the spring of 2000. Most samples were collected using an integrated suspended sediment sampler. The sites that were equipped with GLS auto-sampling units collected samples as water levels rose and were collected within a few hours of the sample time. Water samples were then filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD. The laboratory then analyzed the following parameters:

Fecal Coliform Bacteria
Total Solids
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus
Alkalinity
Total Dissolved Solids
Ammonia
Total Kjeldahl Nitrogen (TKN)
Volatile Total Suspended Solids

Personnel conducting the sampling at each of the sites recorded visual observations of weather and stream characteristics.

Precipitation	Wind
Odor	Septic
Dead Fish	Film
Turbidity	Width
Water Depth	Ice Cover
Water Color	

Parameters measured in the field by sampling personnel were:

Water Temperature	Air Temperature
Conductivity	Dissolved Oxygen
Field pH	

Annual Tributary Loadings

The loads calculated at subwatershed MC-6 are the total loads to Cottonwood Lake. The loadings in Table 14 were calculated using FLUX, an Army Corps of Engineers flow model. The FLUX load indicates in kg/yr the amount of nutrients and sediments predicted to enter Cottonwood Lake. The concentration is in mg/L or parts per million (ppm). This indicates the average concentration of nutrients and sediments that were found in the water entering the lake.

The coefficient of variance (cv) is an indication of the standard error that is anticipated with the data set used to calculate the loads. Lower cv indicates greater accuracy along with a higher confidence in the load calculation. These loading concentrations are used in BATHTUB, an Army Corps of Engineers eutrophication model, to calculate the expected trophic state of the lake as well as the potential trophic state upon reduction of these loads.

Table 14. Predicted Annual Loadings from Medicine Creek

Predicted Annual Lake Loadings from Medicine Creek			
Parameter	FLUX Load (kg/YR)	Conc. mg/L (ppm)	CV
Total Phosphorus	5,894	0.618	0.130
Total Dissolved Phosphorus	3,468	0.364	0.292
Total Alkalinity	3,804,471	399	0.015
Total Solids	15,981,300	1676	0.203
Total Dissolved Solids	14,730,840	1545	0.164
Total Suspended Solids	979,173	103	0.316
Ammonia	119	0.012	0.199
Nitrate/ Nitrite	594	0.062	0.205
Total Kjeldahl Nitrogen	22,355	2.34	0.038
Total Nitrogen	22,949	2.41	0.032
Organic Nitrogen	22,236	2.33	0.039
Inorganic Nitrogen	713	0.07	0.204
Total Volatile Suspended Solids	275,964	29	0.766

Seasonal Tributary Loadings

Seasonal loading of nutrients to Cottonwood Lake from Medicine Creek was greatest during the spring and early summer, as is commonly found on many streams in South Dakota. Table 15 lists monthly concentrations and loads as well as an average monthly concentration for each season.

Calculations to obtain the monthly concentrations and loads were completed with FLUX. Samples and flows that were sampled in Medicine Creek were best utilized by stratifying the data (breaking into 2 groups for load calculation). This site was stratified at the mean flow rate. Flows that were greater than the mean rate were calculated using one concentration while those that were less than the mean rate were calculated using a different concentration. For example, the mean concentration of total phosphorous for flows that were greater than the mean flow rate was 669 ppb while the mean concentration for flows less than the flow rate was 266 ppb. To calculate the mean monthly concentration, an average of the concentrations for all of the flows that occurred greater and less than the mean flow is calculated using the estimation method which best fits the stream, which is the International Joint Commission (IJC) method for this site. The monthly loads are calculated in much the same way. The load that is calculated for each day is dependent on the flow for that day. The sum for all of the days in each month is then calculated, which is the resulting load.

The calculated load for nutrients and sediments for May samples in 1999 and 2000 are not representative of the full months loading. The May 1999 load accounts for only 20 days while the May 2000 load accounts for only the first 15 days of the month. Even with the reduced load, the monthly loads were the highest recorded during May 1999. This is because that month experienced flows that were several magnitudes higher than what occurred during the remainder of the year (see flow volume columns in Table 15).

The average monthly concentration (Spring, Summer, Fall, and Winter section of Table 15) was highest during spring runoff for all of the nutrients and sediment with the exception of volatile suspended solids and inorganic nitrogen. The volatile suspended solids exception is the result of insufficient data for stratification, resulting in the use of the same mean concentration for all flows. The inorganic nitrogen was the greatest during the fall and winter. This is most likely the result of dilution. Spring and summer flows are large enough that when combined with the relatively small amount of inorganic nitrogen found in the stream system, the concentrations are reduced.

Table 15. Monthly and Seasonal Loads at Site MC-6 (Inlet to Cottonwood Lake)

Days Measured		Flow Volume (hm3)	Total Phosphorus Mass (kg)	Total Phosphorus Conc (ppb)	Tot. Dis. Phosphorus Mass (kg)	Tot. Dis. Phosphorus Conc (ppb)	Total Nitrogen Mass (kg)	Total Nitrogen Conc (ppb)	Organic Nit. Mass (kg)	Organic Nit. Conc (ppb)	Inorganic Nit Mass (kg)	Inorganic Nit Conc (ppb)
May-99	20	6.287	4,282	681	2,584	411	16,130	2,565	15,668	2,492	462	73.54
Jun-99	30	1.217	782	643	466	383	3,002	2,468	2,912	2,393	90	74.15
Jul-99	31	0.177	48	271	19	109	266	1,508	252	1,428	14	80.13
Aug-99	31	0.186	50	271	20	109	280	1,508	265	1,428	15	80.13
Sep-99	30	0.069	19	271	8	109	104	1,508	98	1,428	6	80.13
Oct-99	31	0.050	14	271	6	109	76	1,508	72	1,428	4	80.13
Nov-99	30	0.052	14	271	6	109	79	1,508	75	1,428	4	80.13
Dec-99	31	0.022	6	271	3	109	34	1,508	32	1,428	2	80.13
Jan-00	31	0.000	-	271	-	109	-	1,508	-	1,428	-	80.13
Feb-00	29	0.000	-	271	-	109	-	1,508	-	1,428	-	80.13
Mar-00	31	0.520	153	294	66	126	815	1,568	774	1,488	42	79.75
Apr-00	30	0.712	350	491	193	271	1,478	2,074	1,423	1,998	55	76.6
May-00	15	0.346	138	400	71	204	637	1,842	610	1,763	27	78.05
Spring		**1.966**		**467**		**253**		**2,012**		**1,935**		76.99
Summer		0.527		395		200		1,828		1,750		78.14
Fall		0.057		271		109		1,508		1,428		**80.13**
Winter		0.007		271		109		1,508		1,428		**80.13**

Days Measured		Flow Volume (hm3)	Tot. Sus. Solids Mass (kg)	Tot. Sus. Solids Conc (ppb)	Tot. Vol. Sus. Sol Mass (kg)	Tot. Vol. Sus. Sol Conc (ppb)	Total Solids Mass Metric Tons	Total Solids Conc (ppm)	Total Dis. Solids Mass Metric Tons	Total Dis. Solids Conc (ppm)	Total Alkalinity Mass (kg)	Total Alkalinity Conc (ppb)
May-99	20	6.287	706,313	112,337	182,367	29,005	10,951	1,742	10,088	1,605	2,570,819	408,879
Jun-99	30	1.217	128,533	105,648	35,288	29,005	2,061	1,694	1,901	1,563	489,963	402,725
Jul-99	31	0.177	7,082	40,119	5,120	29,005	217	1,228	203	1,152	60,444	342,432
Aug-99	31	0.186	7,452	40,119	5,388	29,005	228	1,228	214	1,152	63,609	342,432
Sep-99	30	0.069	2,761	40,119	1,996	29,005	85	1,228	79	1,152	23,564	342,431
Oct-99	31	0.050	2,016	40,119	1,457	29,005	62	1,228	58	1,152	17,204	342,432
Nov-99	30	0.052	2,097	40,119	1,516	29,005	64	1,228	60	1,152	17,902	342,431
Dec-99	31	0.022	902	40,119	652	29,005	28	1,228	26	1,152	7,695	342,431
Jan-00	31	0.000	-	40,119	-	29,005	-	1,228	-	1,152	-	342,432
Feb-00	29	0.000	-	40,119	-	29,005	-	1,228	-	1,152	-	342,432
Mar-00	31	0.520	22,988	44,217	15,079	29,005	654	1,258	612	1,177	179,987	346,202
Apr-00	30	0.712	56,133	78,791	20,664	29,005	1,071	1,503	993	1,394	269,305	378,014
May-00	15	0.346	21,737	62,888	10,025	29,005	481	1,390	447	1,294	125,601	363,381
Spring		**1.966**		**74,558**		**29,005**		**1,473**		**1,368**		**374,119**
Summer		0.527		61,962		**29,005**		1,384		1,289		362,529
Fall		0.057		40,119		**29,005**		1,228		1,152		342,431
Winter		0.007		40,119		**29,005**		1,228		1,152		342,432

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the intestines of all warm-blooded animals including livestock and wildlife. When feces are delivered to a body of water, fecal coliform bacteria are detectable. Fecal coliform counts varied from values that were below detection limits for several samples to a maximum count of 130,000 detected at MC-4 on April 20, 2000, following a rainfall event. Individual sample results depicted in Figure 9 are in chronological order by sample date. Only those samples greater than 100 colonies/ 100 ml are listed.

The highest concentrations of fecal coliforms were most frequently recorded at site MC-4, which has several animal feeding operations in the immediate upstream vicinity. Subwatersheds MC-2 and MC-5 also consistently produced concentrations of fecal coliform in excess of 100 colonies/ 100mL.

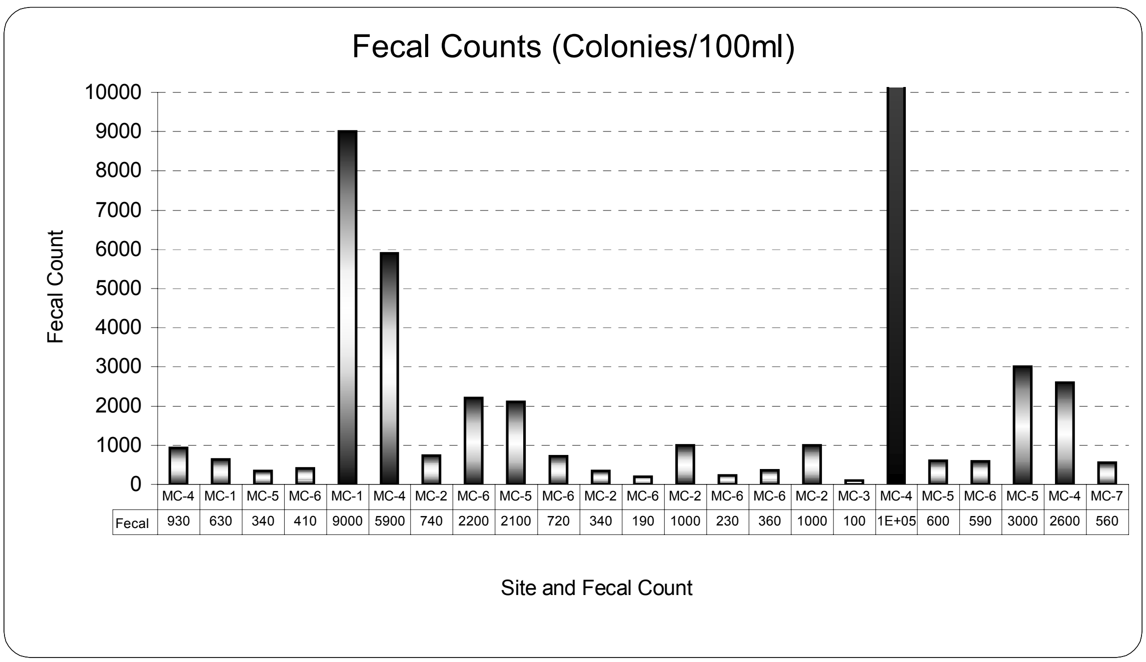
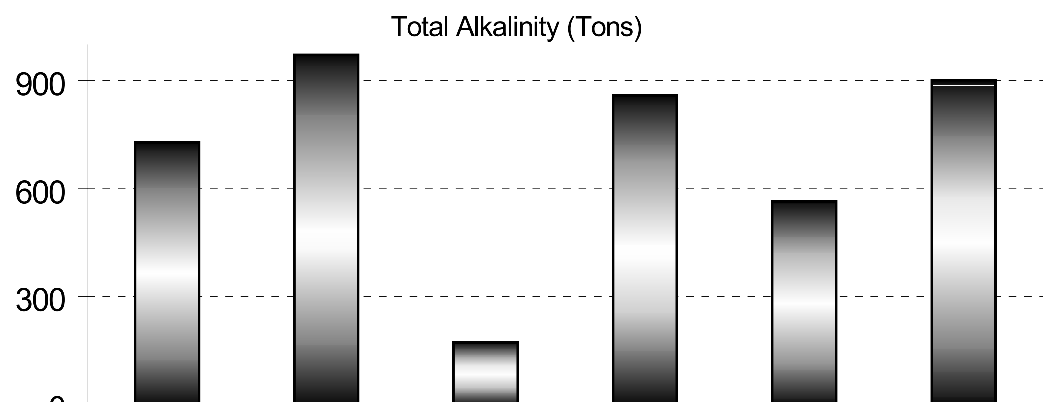


Figure 11. Fecal Coliform Counts by Site Exceeding 200 colonies/ 100 mL in Medicine Creek

Alkalinity

The capacity of water to buffer against acidic pH shifts is often linked to its total alkalinity. Total alkalinity consists of all dissolved species with the ability to accept and neutralize protons (Wetzel, 2000). Due to the abundance of carbon dioxide (CO_2) and carbonates, most freshwater contains bicarbonates as the primary source of alkalinity. It is commonly found in concentrations as high as 200 mg/L. State beneficial use standards require levels to remain below 750 mg/L. The highest individual sample collected was 456 mg/L and was taken from MC-5 on April 27th, 2000. A net loss in alkalinity load occurred at site MC-7 and would suggest an accumulation in the lake. This accumulation would be expected to increase the alkalinity of the lake if this is typical of a "normal" year in respect to loadings.



	MC-1	MC-2	MC-3	MC-4	MC-5	MC-6
Tons	728	972	171	858	565	901

Figure 12. Total Alkalinity Loads by Site in Medicine Creek

Solids

Total solids are the sum of all dissolved, suspended, organic, and inorganic compounds. The total solids load closely resembles the dissolved solids portion of the load. This is due to the fact that dissolved solids composed the majority of the solids load. There are no state standards for total solids concentrations, but for dissolved solids the maximum allowable concentration is 2,500 mg/L for a 30 day mean or 4,375 mg/L for a single daily sample. Total solids and total dissolved solids loads were the greatest from subwatershed MC-4. There was a net loss of dissolved solids in subwatershed MC-6, this loss may be the result of natural variation in groundwater and soils.

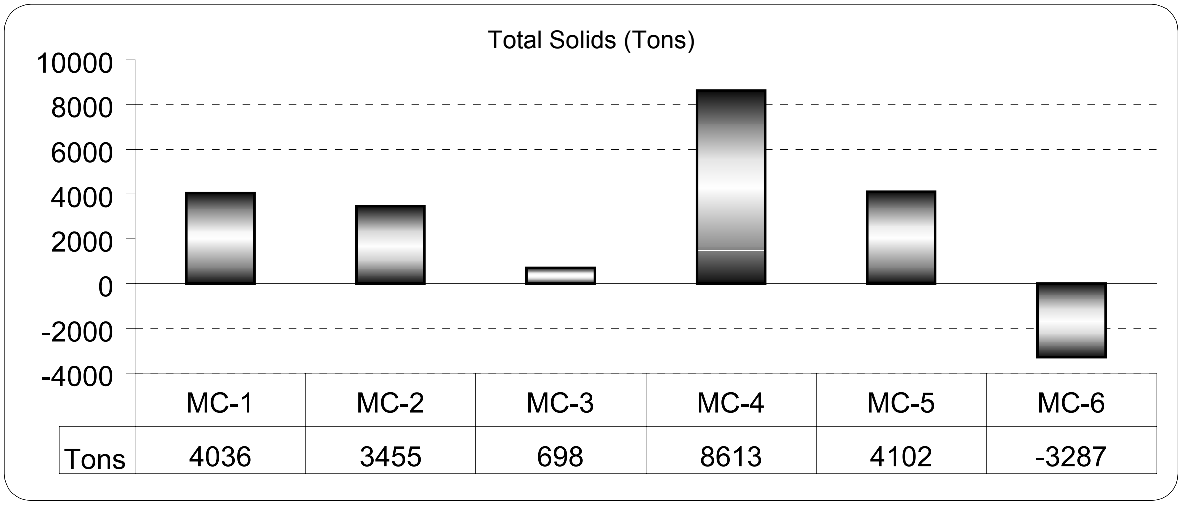


Figure 13. Total Solids Loads by Site in Medicine Creek

There were no exceedences of this standard, however at two separate sites, notably high concentrations were recorded. On April 20, 2000, site MC-1 produced a concentration of 2,845 mg/L. Site MC-4 also produced exceptionally high concentrations on three separate dates of 2,582, 2,956, and 3,184 on March 9, April 20, and April 27 of 2000, respectively. The soils in this area have high amounts of calcium and other ions that are dissolved during storm runoff events. All of the high concentrations occurred during spring rainfall events. High dissolved solids are of greatest concern to livestock owners in the area. High concentrations of dissolved solids can negatively impact livestock health by causing scours and dehydration.

Total suspended solids can be defined as the sum of organic and inorganic materials found in suspension within a water body. The suspended solids carrying capacity of water is proportional to its velocity. When a stream enters a lake, its velocity decreases allowing its suspended solids load to precipitate out in the form of sediment. This process slowly reduces the volume of water in the lake by raising the bottom. The end result is acceleration in the eutrophication process as greater amounts of light are able to reach the bottom and promote plant growth. Suspended solids are most commonly linked to soil loss and erosion due to a number of practices including excessive grazing of rangeland and low residue tillage practices on cropland.

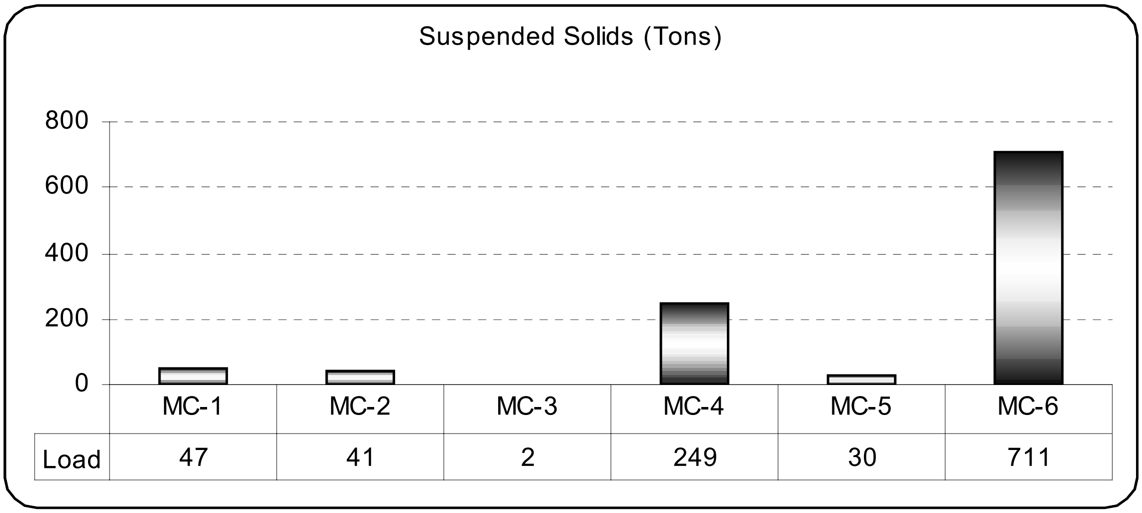


Figure 14. Total Suspended Solids Loads by Site in Medicine Creek

The upper portions of the watershed contributed fairly small loads of suspended solids. Subwatersheds 4 and 6 contributed 23% and 66% of the load, respectively. These subwatersheds comprise 28% of the total acreage in the drainage area, but they combined for a total of 89% of the suspended sediment load. The most likely sources of solids were unstable stream banks.

Volatile suspended solids consist primarily of organic solids in suspension. Volatile solids loads were relatively low compared to the total suspended solids load, and composed approximately 28% of the total suspended solids load. This is significant because 72% of the suspended solids load is made up of inorganic solids. Approximately 98% of the volatile suspended solids load came from subwatersheds MC-4 and MC-6.

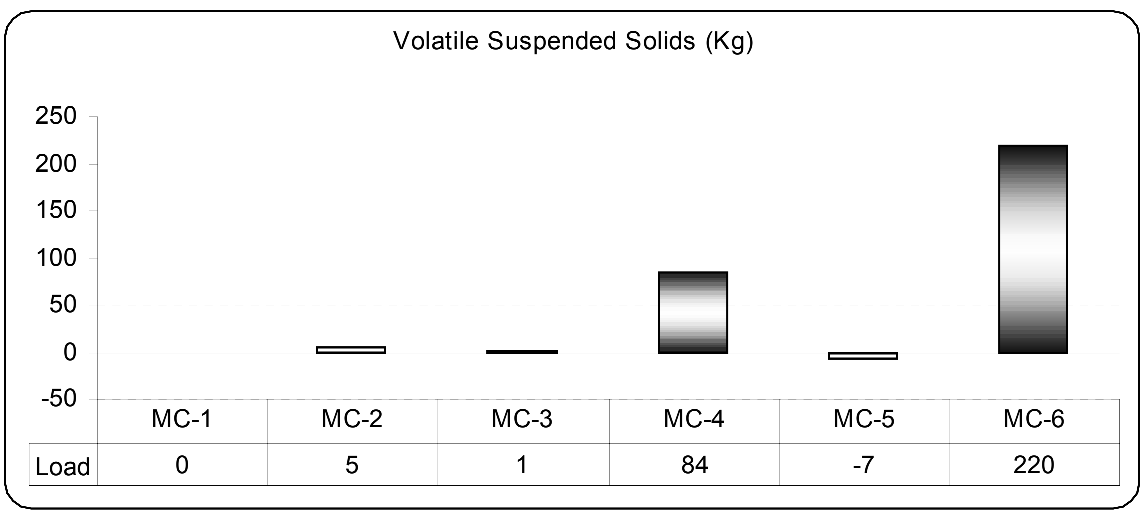


Figure 15. Volatile Suspended Solids Loads by Site in Medicine Creek

Nitrogen

Nitrogen is measured in three forms; TKN, ammonia, and nitrate-nitrite. Organic nitrogen can be calculated by subtracting the ammonia fraction of a sample from its TKN. Nitrogen loads may originate from a variety of sources; animal waste, plant detritus, fertilizer runoff, and directly from the atmosphere. Due to its highly soluble nature in water, it is not an ideal nutrient to use for eutrophication management of lakes.

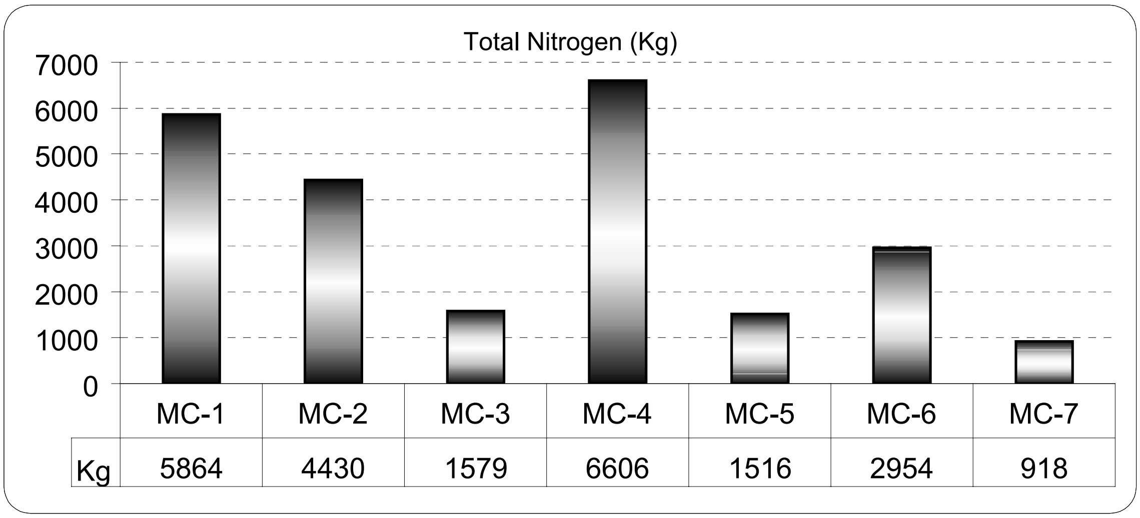


Figure 16. Total Nitrogen Load by Site in Medicine Creek

The total nitrogen load to Cottonwood Lake is 22,949 kg/year. It was calculated as the sum of nitrate-nitrite and TKN. When this load was broken down into its organic and inorganic components, approximately 3% of the load was found to be of an inorganic nature. The remaining 97%, or 22,235 kg was organic. Subwatershed MC-4 accounted for 28% of the total nitrogen load. When the load for this subwatershed is weighted for its acreage, an average load per acre was produced that was two times as large as the watershed average of 0.17kg/acre. Subwatershed MC-6 also exhibited loadings per acre that were larger than the watershed average. Nitrate-nitrite is the most common form of inorganic nitrogen. (Wetzel, 2000). A loss in nitrate-nitrite was exhibited in subwatershed MC-6 (Figure 15) even though the total nitrogen for this subwatershed increased and exhibited one of the higher loadings per acre.

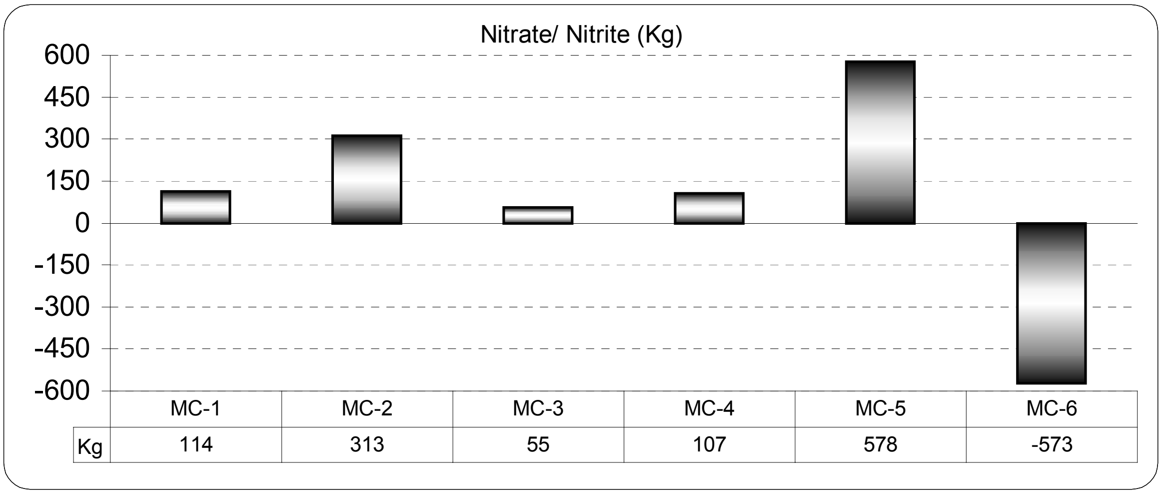


Figure 17. Total Nitrate/ Nitrite Loads by Site in Medicine Creek

TKN is the sum of organic nitrogen and ammonia, and composed the majority of the total nitrogen load. Ammonia composed only a small portion of this load. Ammonia is important because when it is combined with increased temperature and pH levels it can become toxic to fish. Ammonia is often associated with agricultural runoff as well as septic drainage, and is formed when animal and plant wastes are decomposed by some species of bacteria and fungi. Subwatersheds MC-2 and MC-4 generated the greatest loadings of ammonia. When the subwatersheds are weighted for their acreages, subwatersheds MC-4 and MC-5 had the greatest export coefficients, Table 16.

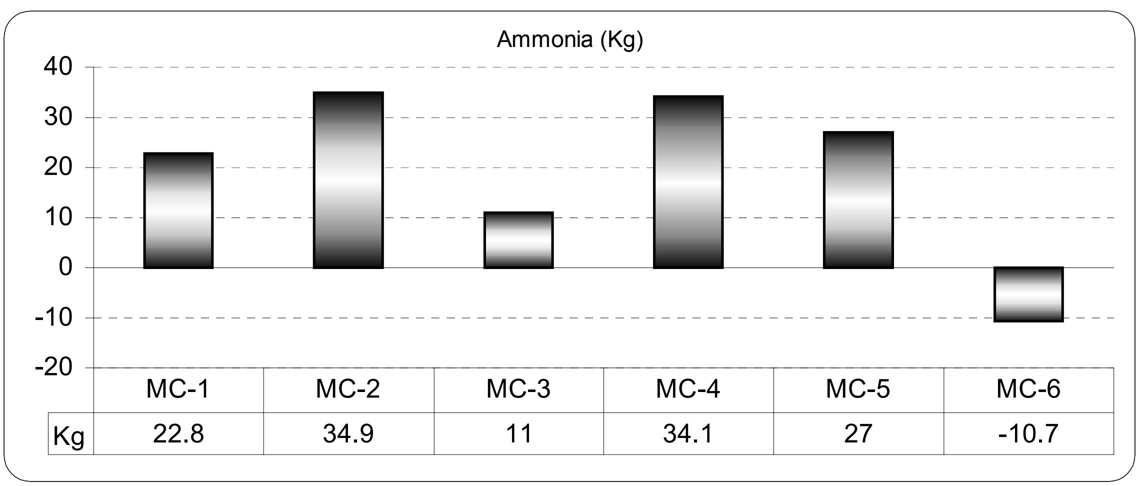


Figure 18. Total Ammonia Loads by Site in Medicine Creek

Phosphorus

Phosphorus is one of the macronutrients required by plant life. It is found in two primary forms in aquatic environments, dissolved in the water and attached to particles suspended in the water. By limiting the supply of phosphorus to a water body, it is possible to inhibit the effects of eutrophication. There are two primary sources of phosphorus in most non-urban watersheds. Soil erosion is the first of these sources. Phosphorus enriched soil particles from cultivated land, often fertilizer enriched, are carried to lakes and streams through soil erosion. This is the primary source for the attached phosphorus portion of the load to Cottonwood Lake. The second source is often associated with Animal Feeding Operations (AFOs). Phosphorus rich manure is washed into lakes and streams during spring snowmelt and rainstorm events. In the case of a watershed like Medicine Creek that has a significant amount of grass and range land, a third source of phosphorus (particularly the dissolved portion) may be from decaying grass and organic material.

The total phosphorus load to the lake from Medicine Creek totaled 5,894 kg. Of the total load, 3,757 kg or 64% originated in subwatersheds MC-1 and MC-2, indicated in Figure 17. These two subwatersheds comprise approximately 54% of the total watershed acreage. Subwatershed MC-6 contributed 2,891 kg or 49% of the total load. Representing only 11% of the drainage, MC-6 contributed 4 times the load per acre of the next highest per acre site, MC-2. Subwatershed MC-5 exhibited a large net consumption of phosphorus. One possible explanation for this could be consumption of phosphorus as the creek flowed through several large stock dams and a large marsh.

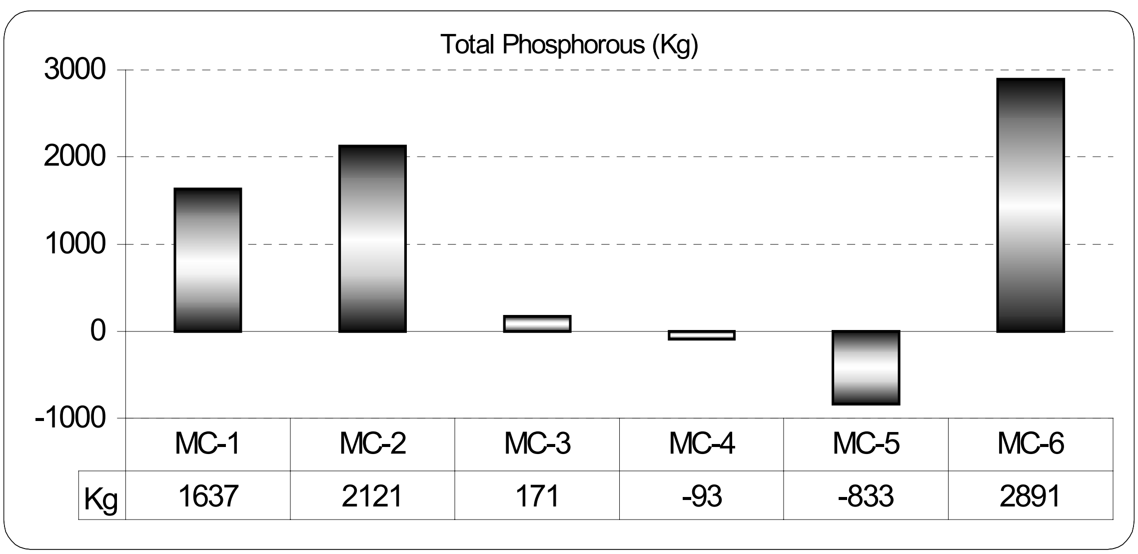


Figure 19. Total Phosphorus Load by Site in Medicine Creek

The percentage of dissolved phosphorus to the total phosphorus load at sites MC-1 and MC-2 was 89% and 91% respectively. This high percentage of dissolved phosphorus indicates that the source was most likely something other then erosion from fields. Further validation of this comes when the suspended solids loads for these subwatersheds are examined (Figure 12). Both subwatersheds had very low suspended solids loadings. The most likely source was AFO discharge into the system.

The percentage of total dissolved phosphorus at the inlet to the lake (Site MC-6) was considerably lower at 59%. This is most likely due to the increased sediment load. This is reinforced when the data for total dissolved phosphorus is examined. Figure 18 shows that there was actually a net loss of dissolved phosphorus as it reached the lower portion of the watershed, particularly in subwatersheds MC-4 and MC-5. The phosphorus in solution attaches to the additional available soil particles. Subwatershed MC-4 had very low total phosphorus consumption (-93.2 kg). However, its dissolved fraction was reduced by 850 kg, approximately 9 times as much. This would suggest that very little phosphorus was added to, or consumed by this subwatershed. MC-4 had a very high suspended solids load (Figure 12). As solids became available, the dissolved phosphorus was able to attach to the suspended soil particles. This would suggest that the sediment was low in phosphorus, most likely from sources other than cultivated fields. One possible source may have been from subsoil along eroded stream banks.

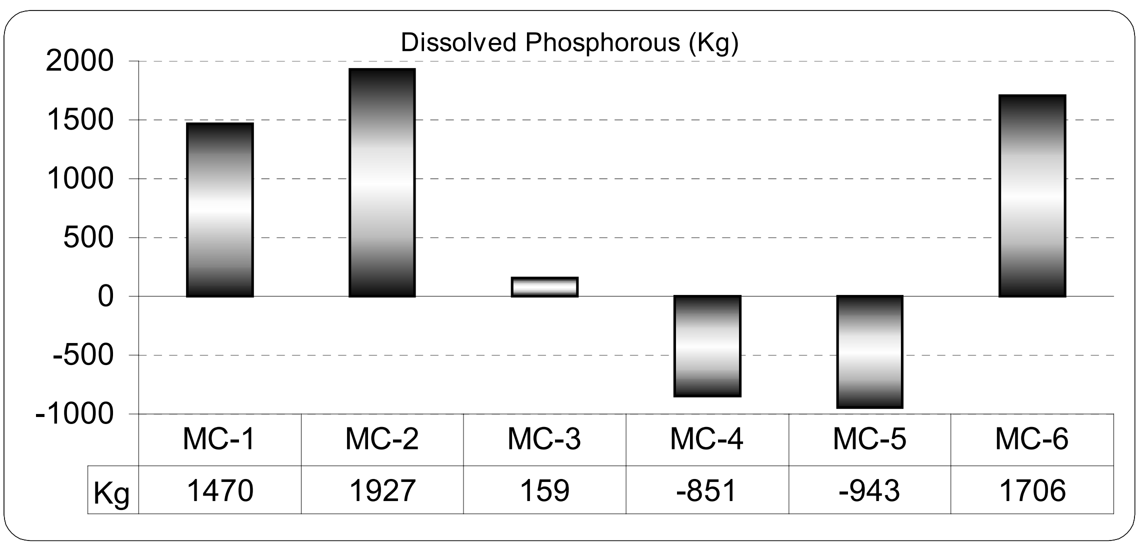


Figure 20. Total Dissolved Phosphorus Loads by Site in Medicine Creek

Tributary Site Summary

When considering all of the data from the previous discussions, two of the subwatersheds appeared to be the most impaired. SiteMC-6 exhibited excessive suspended solids, nitrogen, and phosphate loads. Site MC-4 produced large fecal coliform counts on several occasions as well as having high nitrogen and suspended solids loads. Two other subwatersheds also exhibited the characteristics of impairment. Site MC-2 consistently produced fecal counts over 200/ml and had phosphorus loads that were only exceeded by MC-6. Subwatershed MC-1 exhibited high concentrations of fecal coliform on two occasions. This subwatershed also appeared to be a primary contributor of phosphorus to the lake.

Export coefficients were calculated for nutrients and sediments delivered by each subwatershed and may be found in Table 16. Coefficients were calculated by dividing the load (in kg) generated by each subwatershed by the number of acres in that subwatershed. In some instances a negative load for a subwatershed was calculated, this was discussed in detail in the subwatershed section on pages 22 and 23. The two largest values for each parameter (indicated in bold) represent the site with the greatest loadings/acre. Reduction efforts in these subwatersheds will have the greatest impact on the overall load to Cottonwood Lake.

Table 16. Subwatershed Export Coefficients

Export Coefficients (kg/Acre)						
Parameter	MC-1	MC-2	MC-3	MC-4	MC-5	MC-6
Total Phosphorus	0.043	***0.066***	0.015	-0.004	-0.076	***0.207***
Total Dissolved Phosphorus	0.039	***0.060***	0.014	-0.039	-0.086	***0.122***
Total Alkalinity	17.5	27.4	14.1	36.0	***46.7***	***58.5***
Total Solids	97.2	97.2	57.4	***361.8***	***339.5***	-213.4
Total Dissolved Solids	92.1	91.3	55.0	***331.4***	***325.0***	-215.2
Total Suspended Solids	1.14	1.15	0.14	***10.44***	2.45	***46.19***
Ammonia	0.001	0.001	0.001	***0.002***	***0.002***	-0.001
Nitrate/ Nitrite	0.003	***0.010***	0.005	0.005	***0.053***	-0.041
Total Kjeldahl Nitrogen	0.153	0.127	0.068	***0.301***	0.158	***0.252***
Total Nitrogen	0.156	0.137	0.143	***0.306***	0.138	***0.211***
Organic Nitrogen	0.152	0.127	0.067	***0.299***	0.154	***0.253***
Inorganic Nitrogen	0.004	***0.011***	0.006	0.007	***0.054***	-0.042

Ungauged Tributary Sites

Several discrete tributary samples were taken during the project period, their locations are indicated in Figure 1. The sites labeled as MC-41 and MC-51 are located above and below site MC-4 in the watershed. Site MC-41 is approximately 2 miles upstream and MC-51 is 2 miles downstream. Due to the presence of several AFO's on each side of site MC-4, it was determined that sampling above and below them might help to determine their overall impact on the water quality of Medicine Creek. In comparing the concentrations, the most notable difference seen is that of dissolved oxygen (DO). A steady decrease occurred in the stream as it progressed through the area, possibly due to organic matter decomposition. Fecal counts increased dramatically at site MC-4 (high concentrations at this site were common) but then decreased again at the lower site.

Table 17. Ungauged Tributary Site Data

SITE	DATE	DO	COND	pH	TALKA	TSOL	TDSOL	TSSOL	AMMONIA	NITRATE	TKN	TPO4	TDPO4	FECAL	VTSS
MC-41	6/29/99	9.11	NA	8.51	451	2016	1958	29	<.02	<.1	3.11	.914	.715	240	NA
MC-4	6/29/99	4.16	NA	8.29	446	2037	1935	76	0.15	0.1	3.81	0.682	0.483	5900	NA
MC-51	6/29/99	2.46	NA	8.26	383	1589	1526	32	<.02	<.1	2.54	.635	.522	460	NA
MC-22	3/15/00	16.84	1046	7.79	292	1073	1022	2	0.01	0.05	0.34	0.046	0.027	5	1
MC-23	3/15/00	17.7	1455	8.03	557	1510	1433	8	0.01	0.05	3.14	0.639	0.45	5	8
MC-2	3/15/00	NA	1408	7.95	395	1479	1410	3	0.01	0.05	0.7	0.08	0.064	5	1
MC-10	3/15/00	14.61	1699	8.23	450	1701	1636	23	0.01	0.05	1.27	0.193	0.094	10	5
MC-1	3/15/00	16.06	2302	8.32	309	2350	2243	7	0.01	0.05	1.86	0.174	0.062	5	4

Sites MC-22 and MC-23 may be best described as the south and north half of subwatershed MC-2, respectively. Samples were collected at these sites as a result of the extremely high phosphorus concentrations at this site. On this sample date the concentrations at MC-2 were the lowest collected during the project. Other sample data for this site can be found in Appendix G. The north half of this watershed produced sample concentrations over 12 times higher than the south half of the watershed. No definitive sources were identified.

Subwatershed MC-1 also exhibited very high concentrations of phosphorus. This subwatershed was also found to have the highest predicted phosphorus loads from the AGNPS model. Site MC-10 was sampled to isolate several of the highest-ranking AFOs. Again, the phosphorus concentrations were the lowest recorded during the project. Very little can be accurately implied from this sample set.

Inlake Data

During the course of the project a total of 10 water quality sets were taken from three sites at Cottonwood Lake (Figure 19). The first set of samples were comprised of a surface and bottom sample at each site. After the first set of samples was evaluated, it was determined only surface samples would be taken due to the shallow depth of the lake and the similarity between the samples. Samples were taken monthly from June through October of 1999. Each month's data from each of the three sites was averaged for the overall value for that month. A complete list of all lake sample data may be found in Appendix H.

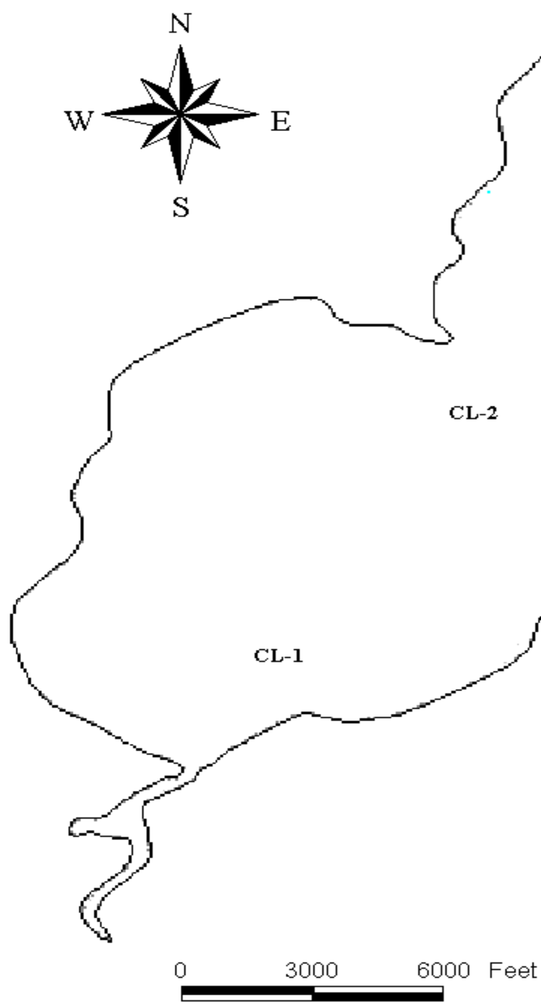


Figure 21. Cottonwood Lake Sampling Sites

South Dakota Water Quality Standards

Every water body within the state of South Dakota has a set of beneficial uses assigned to it. All waters are assigned the use of fish and wildlife propagation, recreation and stock watering. Along with each of these uses are sets of water quality standards that must not be exceeded in order to maintain these uses. Cottonwood Lake has been assigned the beneficial uses of:

(6) Warmwater marginal fish life propagation
(7) Immersion recreation
(8) Limited contact recreation
(9) Fish and wildlife propagation, recreation and stock watering

The following table lists the parameters that must be considered when maintaining the beneficial uses as well as the concentrations for each. When multiple standards for a parameter existed, the most restrictive standard was used. During the course of the project, none of the criteria for the beneficial uses were exceeded.

Table 18. Cottonwood Lake Beneficial Use Standards

Parameters	mg/L (except where noted)	Beneficial Use Requiring this Standard
Alkalinity *($CaCO_3$)*	<750 *(mean)* <1,313 *(single sample)*	Wildlife Propagation and Stock Watering
Coliform, fecal *(per 100 mL)* May 1 to Sept 30	<200 *(mean)* <400 *(single sample)*	Immersion Recreation
Conductivity *(umhos/cm@25 C)*	<4,000 *(mean)* <7,000 *(single sample)*	Wildlife Propagation and Stock Watering
Nitrogen, unionized ammonia as N	<.05 *(mean)* <1.75 *(single sample)*	Warmwater Marginal Fish Propagation
Nitrogen, nitrates as N	<50 *(mean)* <88 *(single sample)*	Wildlife Propagation and Stock Watering
Oxygen, dissolved	>5.0	Immersion and Limited Contact recreation
pH *(standard units)*	6.0 - 9.0	Warmwater Marginal Fish Propagation
Solids, suspended	<150 *(mean)* <263 *(single sample)*	Warmwater Marginal Fish Propagation
Solids, total dissolved	<2,500 *(mean)* <4,375 *(single sample)*	Wildlife Propagation and Stock Watering
Temperature	<32.22^{o} C	Warmwater Marginal Fish Propagation

Inlake Water Quality

Methods

Three sites were selected for monitoring in Cottonwood Lake. Due to the lake's dishpan shape and nearly uniform, shallow depth, the sites were evenly spaced throughout the lake. The first site was located in the southern third, the second was located in the center, and the third site was located in the northern third of the lake. Water samples were collected from the surface of the lake at each of these sites with a Van Dorn sampling device. Bottom samples were collected during June, 1999 to determine if there was any significant difference between surface and bottom water. Due to the shallow nature of the lake (mean depth of 2.0 meters) the samples were nearly identical. The remainder of the samples were collected only from the surface.

Inlake Sampling Schedule

Sampling began in June, 1999 and was conducted on a monthly basis until the project's completion in April, 2000. Water samples were filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD. The laboratory then analyzed the following parameters:

Fecal Coliform Bacteria	Alkalinity
Total Solids	Total Dissolved Solids
Total Suspended Solids	Ammonia
Nitrate	Total Kjeldahl Nitrogen (TKN)
Total Phosphorus	Volatile Total Suspended Solids
Total Dissolved Phosphorus	Chlorophyll *a*

Personnel conducting the sampling at each of the sites recorded visual observations of the following weather and lake characteristics.

Precipitation	Wind
Odor	Septic
Dead Fish	Film
Width	Water Depth
Ice Cover	Water Color

Parameters measured in the field by sampling personnel were:

Water Temperature	Air Temperature
Conductivity	Dissolved Oxygen
Field pH	Turbidity
Secchi Depth	

Water Temperature

Water temperature is of great importance to any aquatic ecosystem. Many organisms and biological processes are temperature sensitive. Blue-green algae tend to dominate warmer waters while green algae do better under cooler conditions. Water temperature also plays an important role in physical conditions. Oxygen dissolves more readily in cooler water. The toxicity of un-ionized ammonia may also be related directly to warmer temperatures.

In order for Cottonwood Lake to maintain its warm water marginal fish life propagation beneficial use, the temperature must remain below 32°C. The warmest temperature experienced by the lake was during the months of July and August when it reached 25° C. This places the lake safely within the required temperature range. As would be expected, temperature is directly affected by the seasons in South Dakota. With just a single year's data, the seasonal temperature changes are very evident (see Figure 20). It can be reasonably expected that during most years the inlake temperatures would be within a few degrees of the sample data at their respective dates.

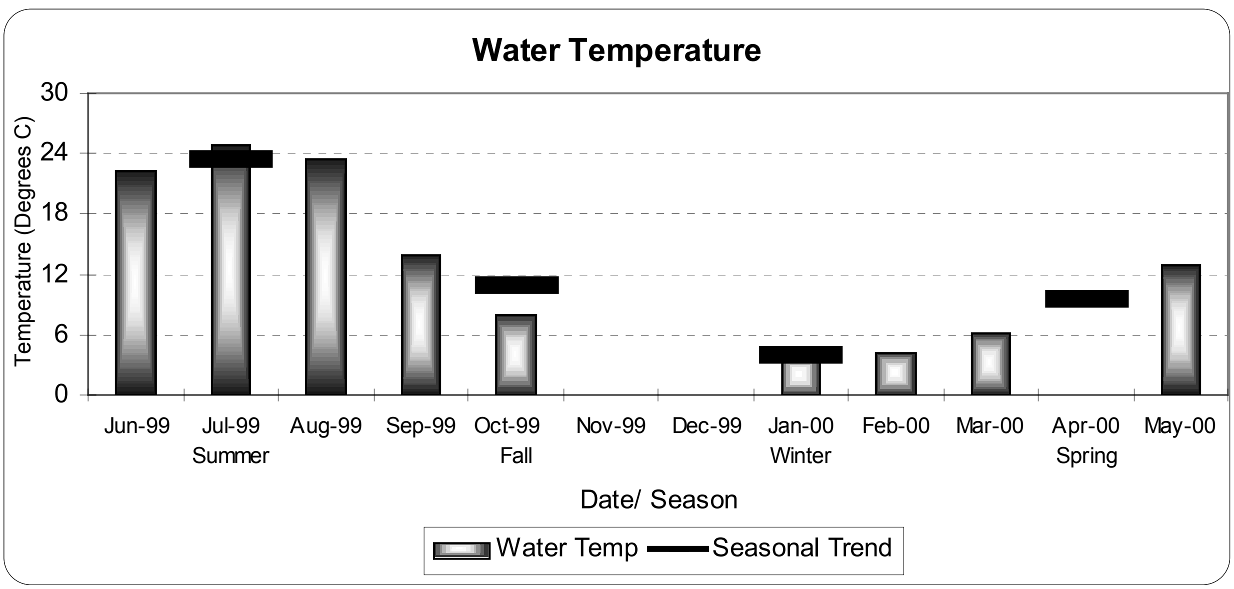


Figure 22. Inlake Average Monthly and Seasonal Temperatures for Cottonwood Lake

Dissolved Oxygen

There are many factors that influence the concentration of dissolved oxygen (DO) in a waterbody. Temperature is one of the most important of these factors. As the temperature of water increases, its ability to hold DO decreases. Daily and seasonal fluctuations in DO may occur in response to algal and bacterial action. (Bowler, 1998) As algae photosynthesize during the day, they produce oxygen, which raises the oxygen concentration in the water. As photosynthesis ceases at night, respiration utilizes available oxygen causing a decrease in concentration. During winters with heavy snowfall, light penetration may be reduced to the point that the algae and aquatic macrophytes in the lake cannot produce enough oxygen to keep up with consumption (respiration) rates. This results in oxygen depletion, which may ultimately end in a fish kill.

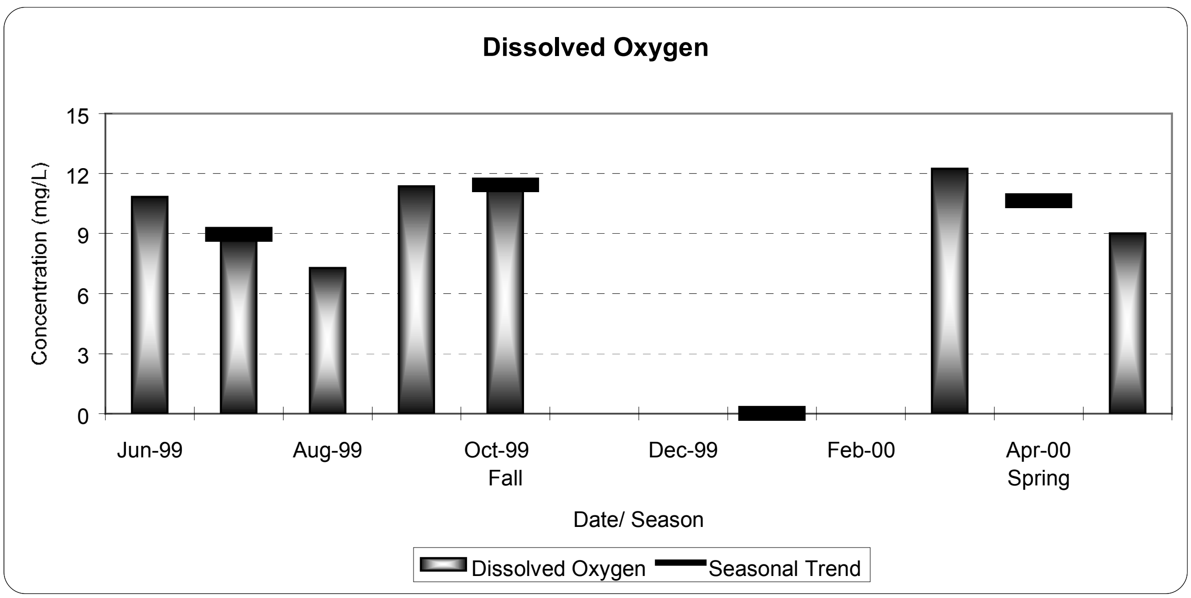


Figure 23. Inlake Average Monthly and Seasonal Dissolved Oxygen Concentrations for Cottonwood Lake

Oxygen levels of 5 mg/L must be maintained as a minimum to support the fishery in Cottonwood Lake. Dissolved oxygen levels were at their highest during the fall. The lowest measured concentration was 7.28 mg/L in August of 1999. This level is sufficient to support the local fishery. DO data from the winter months is unavailable, and is reported seasonally as a 0 in the previous figure. However, the lake remained partially open during most of the winter as a result of unseasonably warm temperatures. Since no fish kill was observed, it can be assumed that oxygen levels remained at sufficient levels. The highest DO levels were recorded during the fall and early spring prior to and immediately following ice cover. The low water temperature associated with these samples most likely accounts for the high DO concentrations.

pH

pH is a measure of free hydrogen ions (H+), and it indicates the balance between acids and bases in water. It is measured on a logarithmic scale between 0 and 14 and is recorded as standard units (su). At neutral (pH of 7) acid ions (H+) equal the base ions (OH-). Values less than 7 are considered acidic (more H+ ions) and greater than 7 are basic (more OH- ions). Algal and macrophyte photosynthesis act to increase a lake's pH. The decomposition of organic matter will reduce the pH. The extent to which this occurs is affected by the lakes ability to buffer against changes in pH. The presence of a high alkalinity (>200 mg/L) will reduce the effects of both photosynthesis and decay in producing large fluctuations in pH.

Cottonwood Lake is well buffered against changes in pH. As a result, very little variation was observed in sample data seasonally. The lake average was 8.53 su with a maximum of 8.93 su and a minimum of 8.16 su. To effectively support the managed fishery, a pH level must be maintained between 6 and 9 su. The lakes highest recorded level of 8.93, as well as its lowest recorded level of 8.16 all fell safely within this range. Due to the very small changes in pH on a monthly basis, very little change was observed seasonally. The highest values were recorded during mid to late fall after the heaviest algae blooms had taken place. It is possible that during and immediately following periods of heavy algae blooms that the pH of the lake may exceed the state standard of 9.00 su.

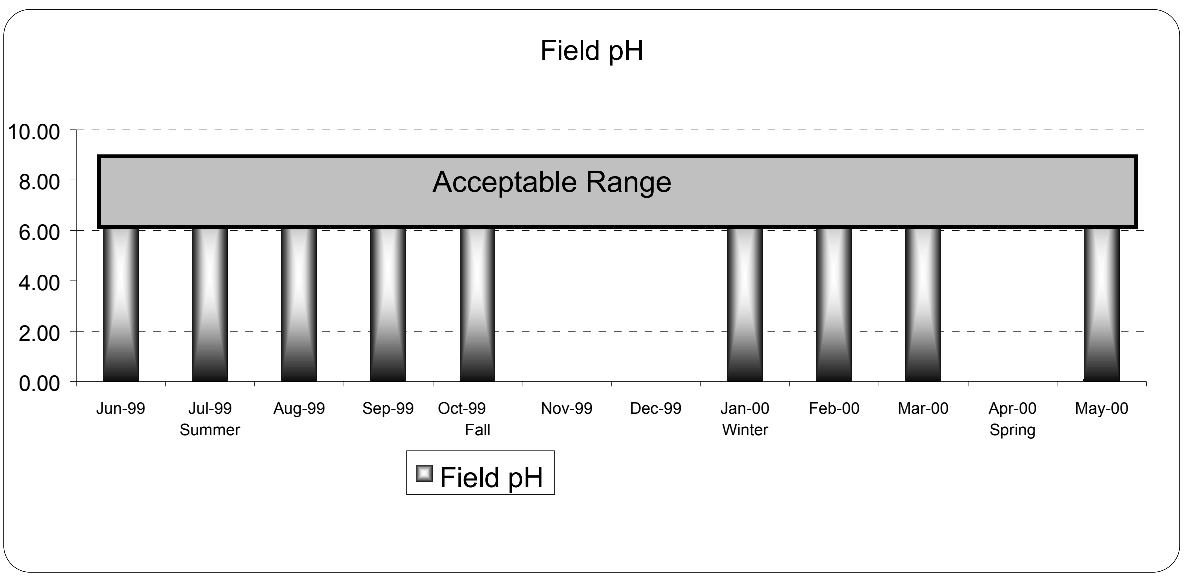


Figure 24. Inlake Average Monthly pH Values for Cottonwood Lake

Conductivity

Conductivity is a measure of water's ability to conduct electricity, which is a function of the total number of ions present. Increases in conductivity reflect the increase in total concentration of dissolved ions in the water body. This may also be used to indicate hardness. It is measured in microhmos/centimeter (umhos/cm), and is sensitive to changes in temperature.

Sample data ranged from 1,483 to 1,842 umhos/cm. While those values are relatively high, they are still less than half of the state standard for the 30 day geometric mean of 4,000 umhos/cm. The state standard for a single sample maximum is 7,000 umhos/cm. The lake is heavily influenced by groundwater, most likely from the Tulare Aquifer. Medicine Creek, which is the primary tributary to the lake, often produced conductivities much greater than the inlake samples and USGS sample data for the Tulare aquifer. This may account for the variation in sample data. The highest conductivity readings were recorded during or after periods of increased flow from Medicine Creek. The decreases in conductivity occurring through late summer and fall correspond with low creek flows and loadings and may be a result of loading dilutions from the groundwater entering the lake, which vary from as low as 700 to as high as 2600 depending on the particular test well from which they were collected.

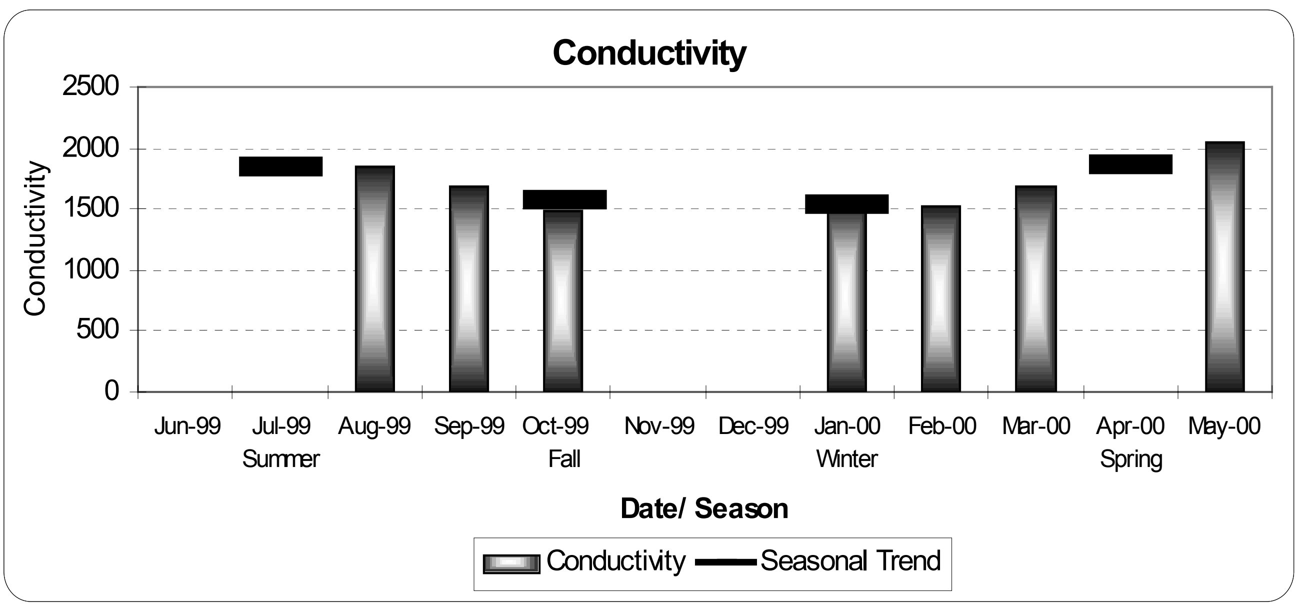


Figure 25. Inlake Average Monthly and Seasonal Conductivity for Cottonwood Lake

Turbidity

Turbidity is a measurement of water transparency or clarity that is affected by the presence of fine suspended particulate matter. Turbidity is measured in Nephelometric Turbidity Units or NTU, which measure reflection and absorption of light when it passes through a water sample. Due to the wide variety of sizes, shapes, and densities of particles, there is no direct relationship between the turbidity of a sample and the concentration and/or weight of the particulate matter present. This is addressed as total suspended solids later in the report. There is no state standard for turbidity in waterbodies, although there is a standard for total suspended solids. It is important to note that high turbidity levels limit photosynthetic activity. (Bowler, 1998)

The suspended sediment in Cottonwood Lake consisted primarily of fine silts and clays. This composition, in combination with the large size and shallow depth of the lake and windy conditions the area experiences, contributed to periods of high turbidity. During periods of ice cover, the turbidity levels remained less than 20. During the spring and summer these levels were considerably higher at 45 to 169 NTU. These periods of high turbidity may be a contributing factor to the scarcity of aquatic macrophytes in the lake. It may also limit the extent of some algae populations. At NTU > 50, feeding dynamics and structure of local fish populations could be affected (Claffey, 1955).

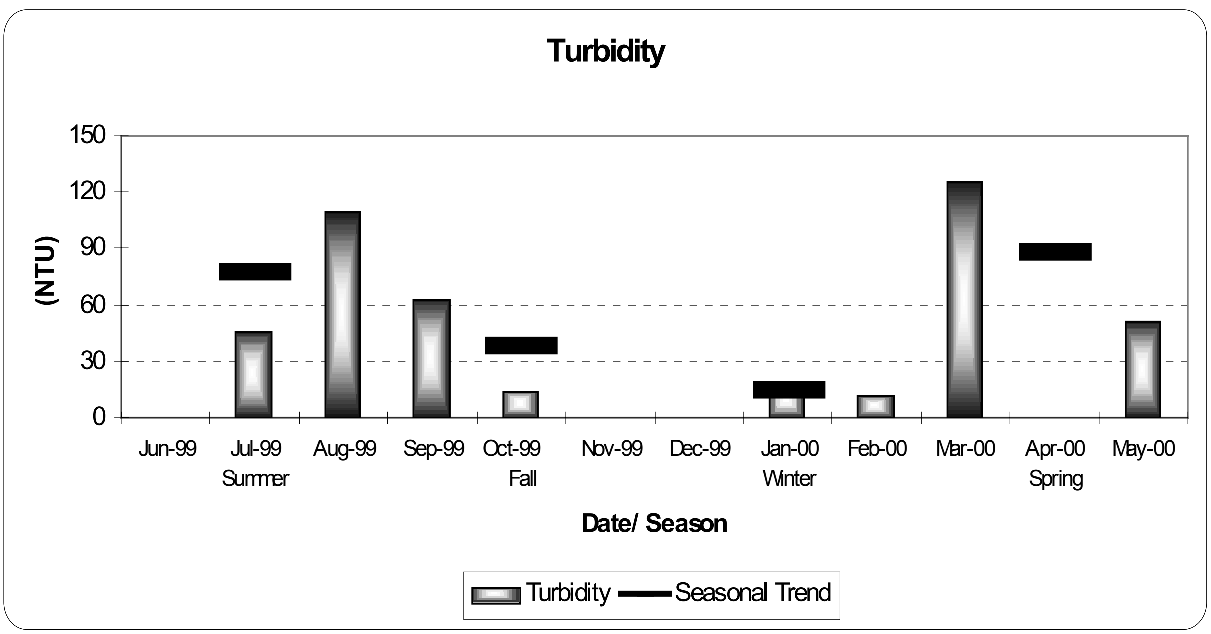


Figure 26. Inlake Average Monthly and Seasonal Turbidity for Cottonwood Lake

Secchi Depth

Secchi depth is a measurement of water clarity. No standards for this parameter exist, however, the Secchi reading is an important tool in determining the trophic state of a lake. The two primary causes for low Secchi readings are suspended solids and algae. Deeper Secchi readings are found in lakes that have clearer water, which is often associated with lower nutrient levels and "cleaner" water.

During the spring and summer months the Secchi reading in Cottonwood Lake varied from less than 0.5 meters to 1 meter. In October, the readings reached 3.0 meters. This was essentially the bottom of the lake. This extremely clear water was the result of some unusually calm weather and the collapse of the summer algae bloom. The lack of wind in the days preceding and during the testing allowed many of the fine sediments to settle out of the water. This theory is reinforced further when compared to the readings taken during the winter months. Ice cover eliminated the effects of wind-induced turbulence in the water resulting in a visibility reaching the bottom. These sediments limit some algae production resulting in better water clarity during times of little or no wind.

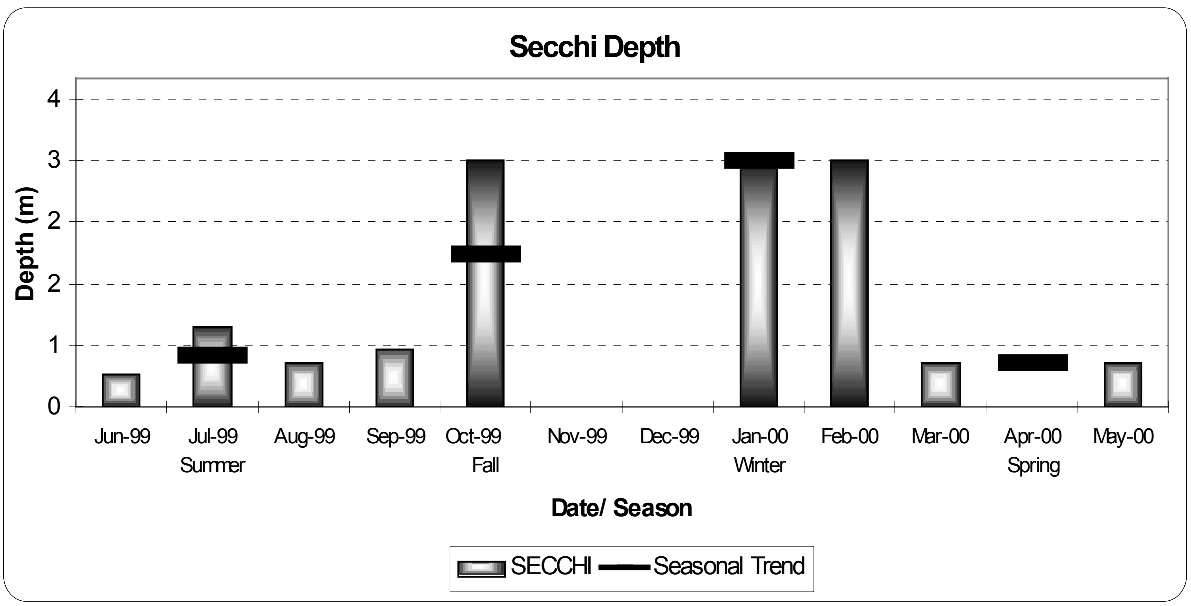


Figure 27. Inlake Average Monthly and Seasonal Secchi Depths for Cottonwood Lake

Alkalinity

A lake's total alkalinity affects its ability to buffer against changes in pH. Total alkalinity consists of all dissolved electrolyte or ion species with the ability to accept and neutralize protons. (Wetzel, 2000). Due to the abundance of carbon dioxide and carbonates, most fresh water contains bicarbonates as their primary source of alkalinity. In nature, alkalinity concentrations are commonly found in concentrations as high as 200 mg/L or more.

Cottonwood Lake's high alkalinity gives it an excellent capacity to buffer against changes in pH. The maximum limit for a lake's alkalinity affecting designated beneficial uses is 750 mg/L. At no point did the lake ever reach this level. A slight increase in the alkalinity was observed during late summer and fall. This may be attributed to an increased influence on the lake from groundwater. On July 30, 1999, the lake was no longer receiving sufficient surface drainage to continue discharging from the outlet. From that point on, the only inflows to the lake consisted of groundwater, flowing cabin wells, and a single rainstorm event that occurred at the end of August. The Tulare Aquifer is the primary source of groundwater to the lake. It has an average alkalinity of 500 mg/L, which is higher than the average lake concentrations, which ranged from 306 to 351 mg/L. Its influence most likely accounts for the seasonal increases that occurred during fall and winter.

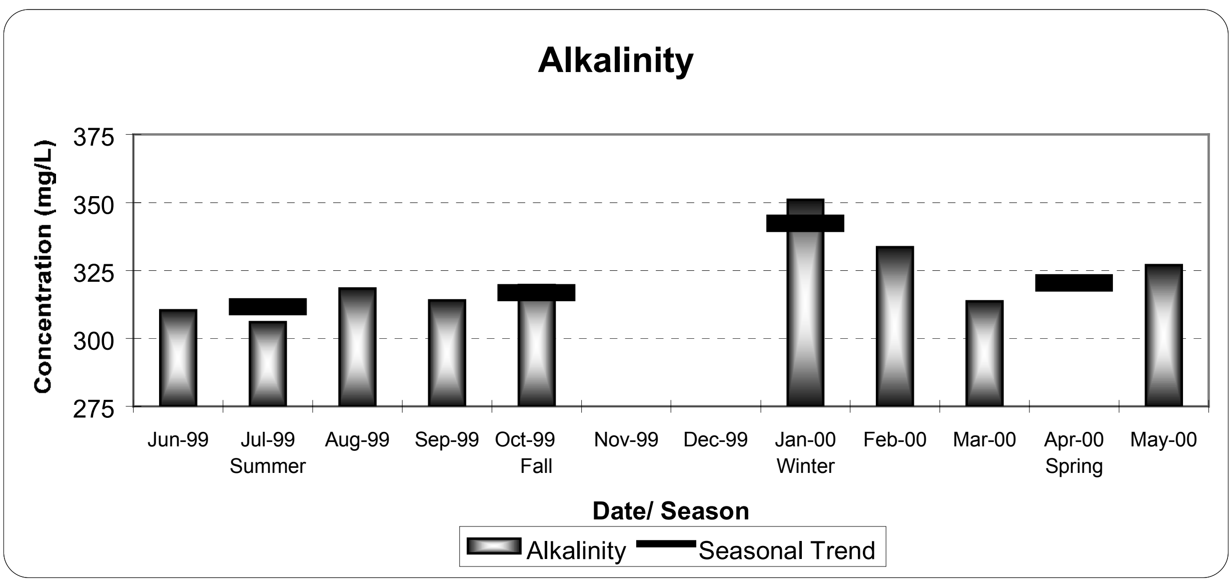


Figure 28. Inlake Average Monthly and Seasonal Alkalinity for Cottonwood Lake

Solids
Solids are addressed as four separate parts in the assessment; total solids, dissolved solids, suspended solids, and volatile suspended solids. Total solids are the sum of all forms of material including suspended and dissolved as well as organic and inorganic materials that are found in a given volume of water.

Total solids loads averaged 1,466 mg/L with a maximum value of 1,609 mg/L on February 1, 2000 and a minimum value of 1,314 mg/L on July 13, 1999. The average concentration for dissolved solids was slightly less at 1,450 mg/L with a maximum value of 1,608 mg/L on February 1, 2000 and a minimum of 1,290 mg/L on June 22, 1999. There are no state standards that deal explicitly with total solids in a water body.

Dissolved solids are those materials, both organic and inorganic, which are in true solution in the water. They constitute a majority of the total solids concentration (>95%). The state standard for this parameter requires it to remain less the 2,500 mg/L. Cottonwood Lake never reached or exceeded this value. The highest concentrations were recorded during the winter months when site CL-3 produced 1,688 mg/L on February 1, 2000.

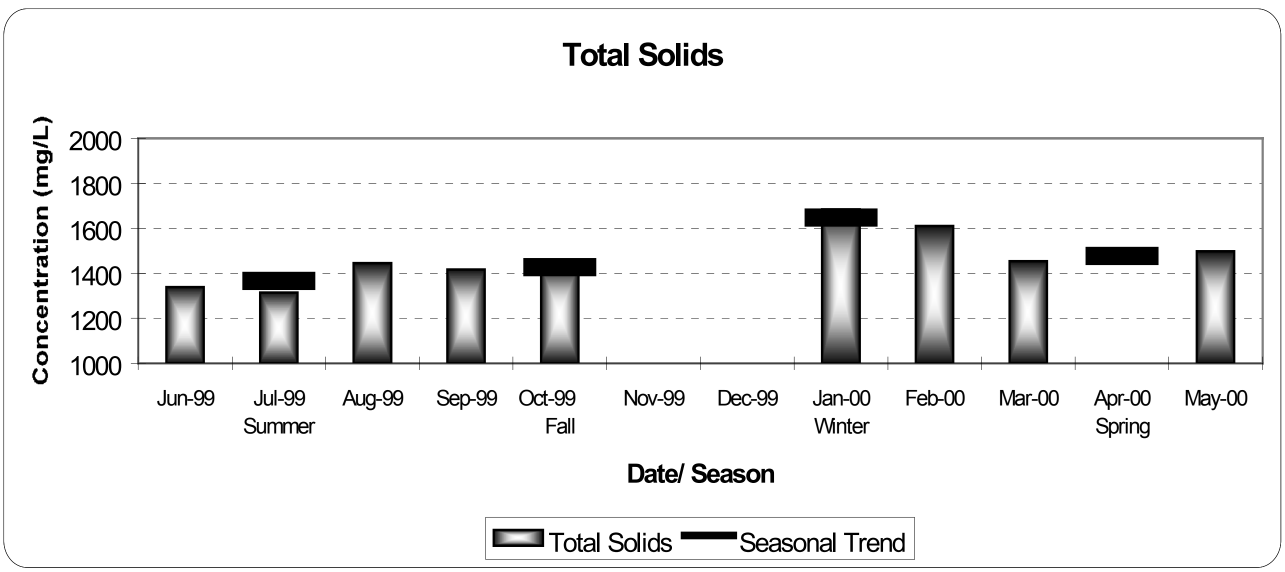


Figure 29. Inlake Average Monthly and Seasonal Total Solids for Cottonwood Lake

Suspended solids consist of particles of soil and organic matter that may be deposited in stream channels and lakes in the form of silt. Silt deposition into a stream bottom buries and destroys the complex bottom habitat. This habitat destruction reduces the diversity of aquatic insect, snail, and crustacean species. In addition to the reduction of stream habitat, large amounts of silt may also fill in lake basins. As silt deposition reduces water depth in a lake, several things occur. Wind-induced wave action increases turbidity concentrations. Shallow, turbid waters increase in temperature faster and remain warmer than clear waters. Shallow water also allows for the establishment of beds of aquatic macrophytes.

Total suspended solids concentrations in Cottonwood Lake averaged 16 mg/L. A maximum value of 48 mg/L was reached in June 1999 while minimum values of 1 mg/L were recorded in January and February of 2000. Total suspended solids levels in Cottonwood Lake were affected by wind conditions as much as Medicine Creek flows and seasons. During the winter, ice cover prevented wind-induced turbidity and there was no inflow from Medicine Creek.

The highest levels of suspended solids in the lake corresponded with dates when storm events occurred and Medicine Creek discharged greater volumes of water to the lake (June, August, and March). Volatile suspended solids are the portions of suspended solids that consist of organic material. Volatile solids composed 36% of the total suspended solids. This is slightly higher than the loads from Medicine Creek where only 28% of the suspended sediment load is composed of volatile materials. The additional organic material found in the lake is most likely from algae.

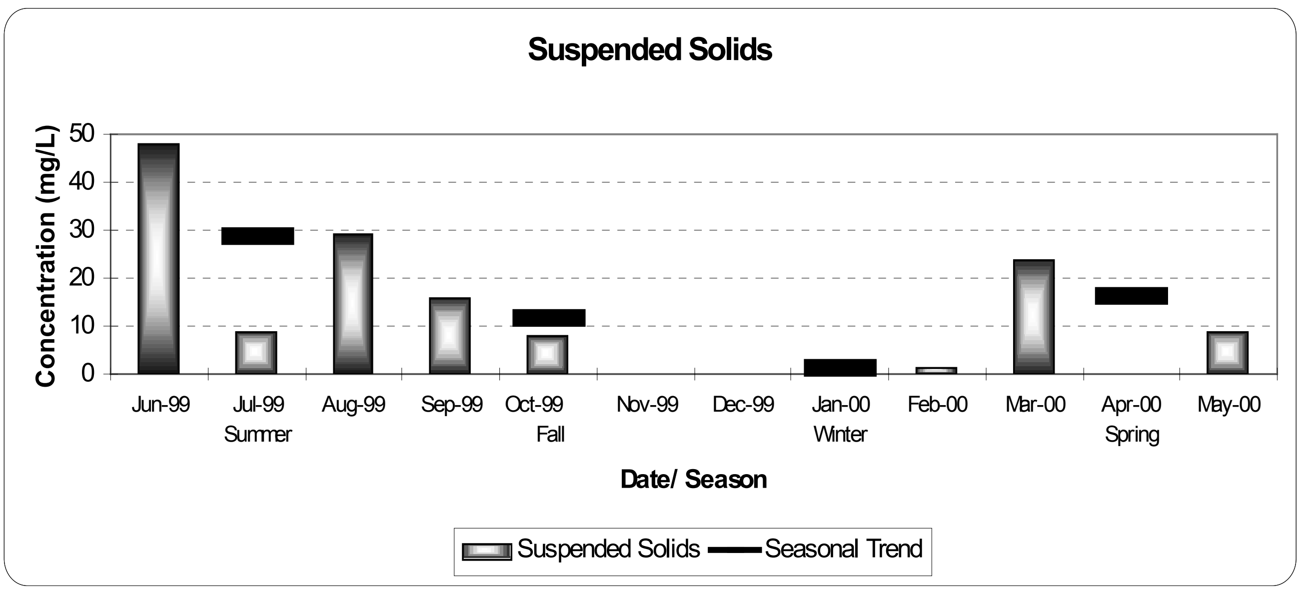


Figure 30. Inlake Average Monthly and Seasonal Suspended Solids for Cottonwood Lake

Nitrogen

Nitrogen is analyzed in 4 forms: nitrate/ nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these four forms total, organic, and inorganic nitrogen may be calculated. Nitrogen compounds are major cellular components of organisms. Because nitrogen availability may often be less than the biological demand, insufficient environmental sources may limit productivity in freshwater ecosystems. Nitrogen is difficult to manage because it is highly soluble and very mobile.

Total nitrogen is the sum of TKN and nitrate/ nitrite. Total nitrogen is primarily used in the calculation of limiting nutrients. The total nitrogen concentrations were found to be highest during late summer and early fall. Maximum concentrations were recorded in September 1999 at 2.51 mg/L. The lowest levels occurred in the winter with the lowest value in February, 2000 at 1.54 mg/L. Seasonally, the total nitrogen concentration appeared to gradually increase through the year until sometime in late fall or early winter when it declines.

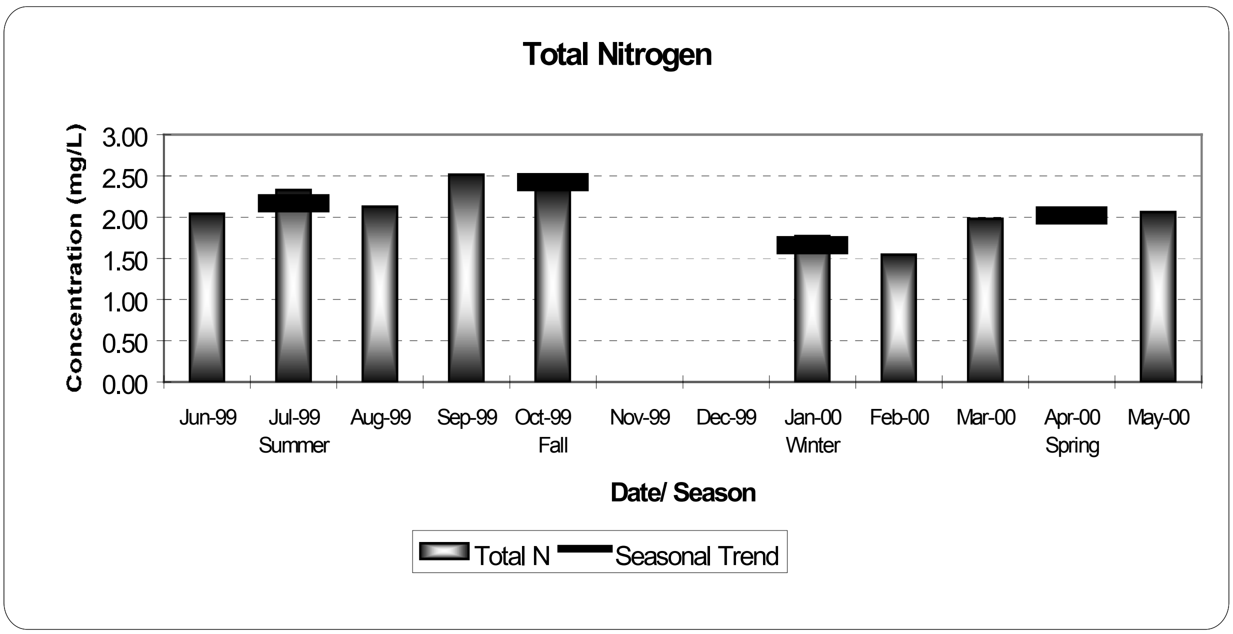


Figure 31 Inlake Average Monthly and Seasonal Nitrogen for Cottonwood Lake

A large portion of the nitrogen found in most freshwater ecosystems is organic in nature. Cottonwood Lake is no exception with nearly 88% of the total nitrogen found in an organic form. Organic nitrogen is not generally available for plant use because it is often found as particulate and dissolved organic detritus. Remineralization may occur when organic forms are exposed to photochemical alteration by UV of natural sunlight (Wetzel, 2000). The average concentration of organic nitrogen in Cottonwood Lake was 1.83 mg/L with a maximum of 2.45 mg/L and a minimum of 1.47 mg/L. Seasonal variations closely resembled the total nitrogen trends with fall producing the highest values and winter producing the lowest values.

The remainder of the lake nitrogen pool was represented by the 12% of inorganic nitrogen that was composed of nitrate-nitrite and ammonia. Nitrate is the most common form of inorganic nitrogen (Wetzel, 2000). While both forms are plant available, ammonia is the most readily available form and produces the highest growth rates when it is available (Wetzel, 1983). In addition to being the most plant available form, ammonia is also the end product of bacterial decomposition of more complex nitrogen compounds.

Sources of nitrate-nitrite include septic tanks, agricultural waste, and other sources of organic waste. Nitrate-nitrite and ammonia are both used by algae and macrophytes for growth. Nitrate levels at Cottonwood Lake were the highest in the summer months. The rest of the year, levels remained relatively low, often below the detection limit. Nitrates reached their peak during the middle of summer in July. A maximum concentration of 0.80 mg/L was recorded during that month. This corresponds to what is typically the peak use of lake cabins indicating that they may be the primary source of nitrates. Runoff during the summer was at a minimum as a result of the limited amount of rainfall that the area received. Nitrogen levels remained lower than the average of 0.19 mg/L for the remainder of the year with the exception of the June 1999 sample, which was recorded at 0.30 mg/L.

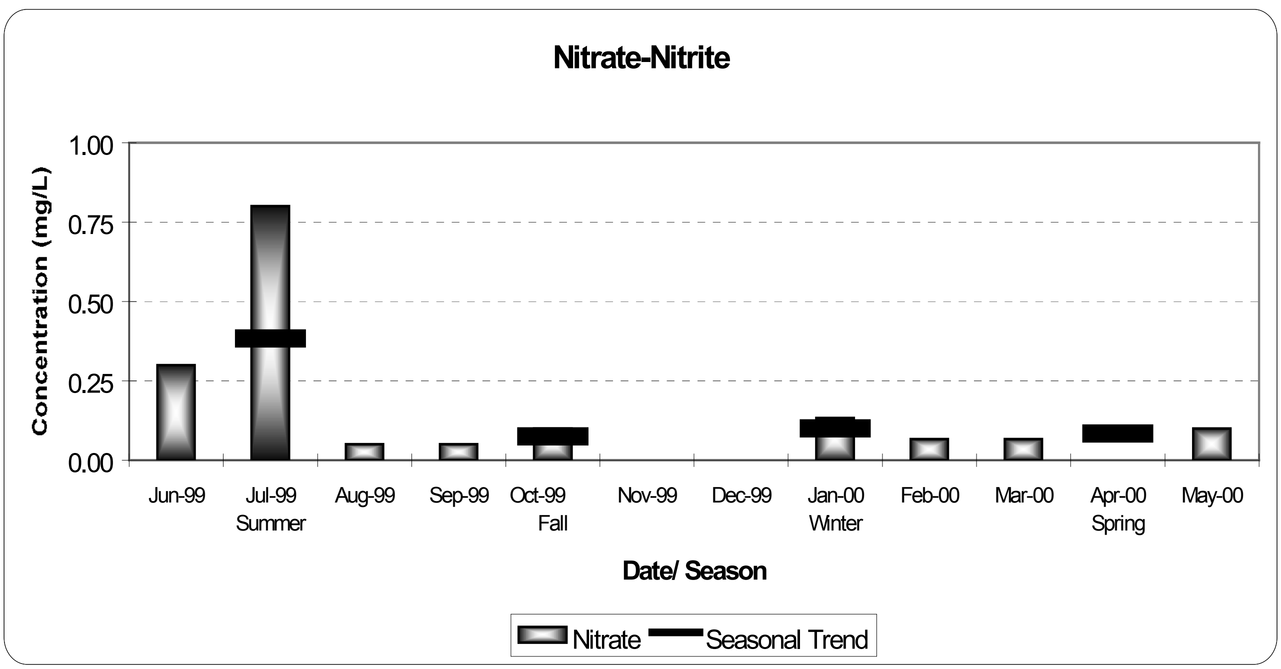


Figure 32. Inlake Average Monthly and Seasonal Nitrate-Nitrite for Cottonwood Lake

Increased levels of ammonia were observed in May, June, and August samples. The highest individual sample was detected at site CL-3 in August of 1999 at a concentration of 0.36 mg/L. Although the highest monthly sample concentration occurred during the summer, the highest seasonal concentration was during the spring, falling just short of 0.10 mg/L. Fall and winter data showed ammonia concentrations that were consistently below the detection limit of 0.02 mg/L.

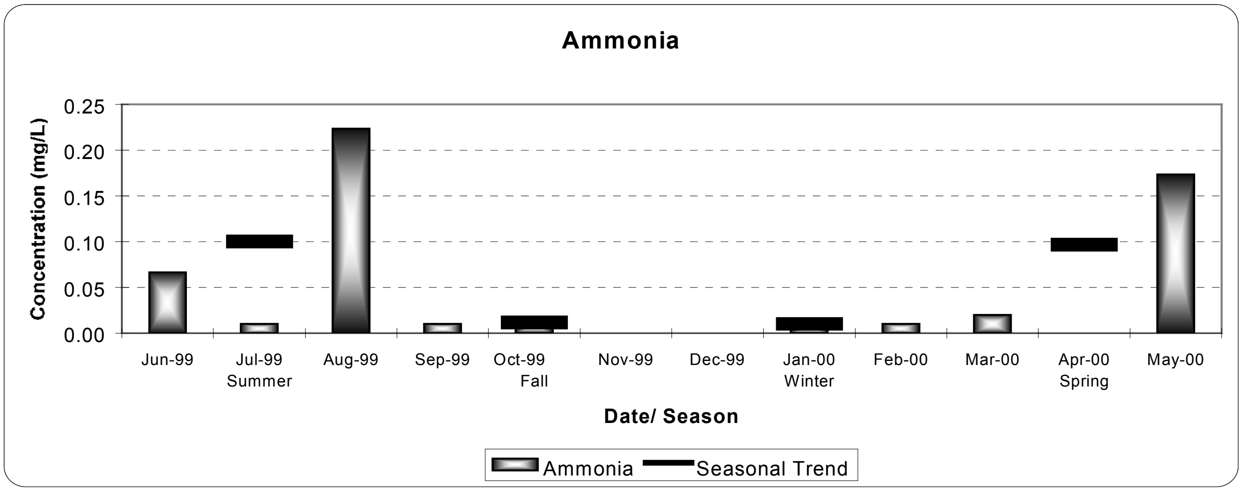


Figure 33. Inlake Average Monthly and Seasonal Ammonia for Cottonwood Lake

Ammonia can be found in two forms, ionized and un-ionized. The latter of the two forms can be extremely toxic to fish. The un-ionized fraction of ammonia is dependent on pH and temperature. As these two parameters increase, so does the un-ionized fraction of ammonia. Ammonia tends to remain in its ionic form (NH_4^+) except under higher alkaline conditions (pH>9.0) (Wetzel, 2000). There were only two samples with un-ionized ammonia values greater than 0.01, August, 1999 and May, 2000. These are also the dates on which the highest levels of total ammonia were recorded. August samples had un-ionized ammonia fractions slightly over 0.01, which was still safely below the 0.05 level that is lethal to fish.

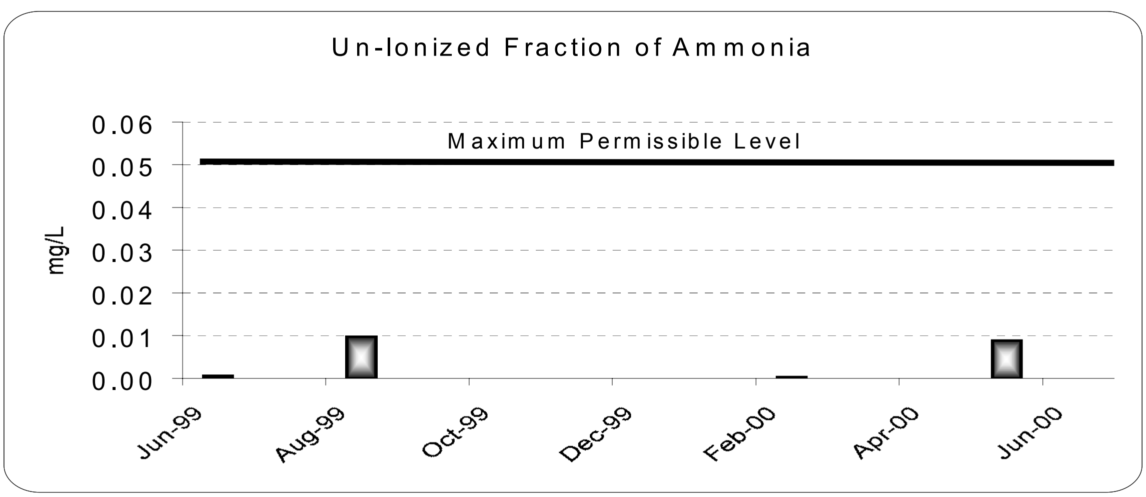


Figure 34. Monthly Un-ionized Fraction of Ammonia Percentages for Cottonwood Lake

Total Phosphorus

Phosphorus is one of the macronutrients required for primary production. In comparison to carbon, nitrogen, and oxygen, it is the least abundant (Wetzel, 2000). Phosphorus loading to lakes can be of an internal or external nature. External refers to surface runoff over land, dust, and precipitation. Internal loading refers to the transfer of phosphorus from the bottom sediments to the water column of the lake. Total phosphorus is the sum of all attached and dissolved phosphorus in the lake. The attached phosphorus is directly related to the amount of total suspended solids present. An increase in the amount of suspended solids increases the fraction of attached phosphorus.

The single highest concentration during this project was collected from site CL-3 on August 26, 1999, with a value of 0.342 mg/L. There are no state standards limiting the concentration of phosphorus in a water body. Total phosphorus is used in the TSI determination as well as the limiting nutrient calculations. The mean concentration at Cottonwood Lake was 0.225 mg/L for the project period. Seasonal variations (Figure 33) show samples having the greatest concentration during the spring at 0.268 mg/L. The lowest concentrations were found in the fall samples with concentrations averaging 0.165 mg/L. The fall concentration average may be lower than what would normally be found due to the extremely low concentrations found in September of 1999. There was no apparent reason why samples collected in September were less than half of the annual average.

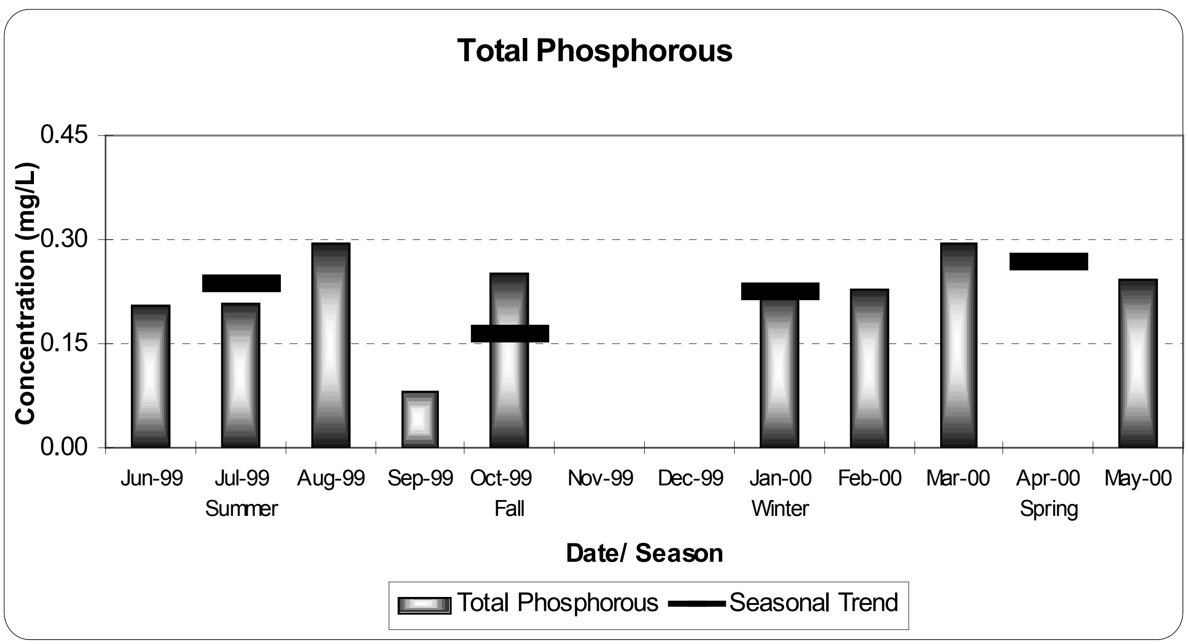


Figure 35. Inlake Average Monthly and Seasonal Total Phosphorus for Cottonwood Lake

Dissolved Phosphorus

Total dissolved phosphorus is the unattached portion of the total phosphorus load. It is found in solution but readily binds to suspended soil particles when they are present. Total dissolved phosphorus, including soluble reactive phosphorus, is more readily available to plant life.

Peak individual samples were reported from CL-2 on February 1, 2000 at a concentration of 0.223 mg/L. Seasonal concentrations varied considerably. As with the total phosphorus concentration, fall samples produced the lowest seasonal concentrations with an average of 0.113 mg/L. This was also due to the exceptionally low concentrations that were sampled during September. Winter and spring concentrations were the highest. Winter concentrations were the highest at 0.207 mg/L and comprised 92% of total phosphorus. The most likely explanation for this is the slow release of phosphorus from the lake sediments coupled with ice cover that kept turbulence borne suspended solids from providing sites for the phosphorus to bind to.

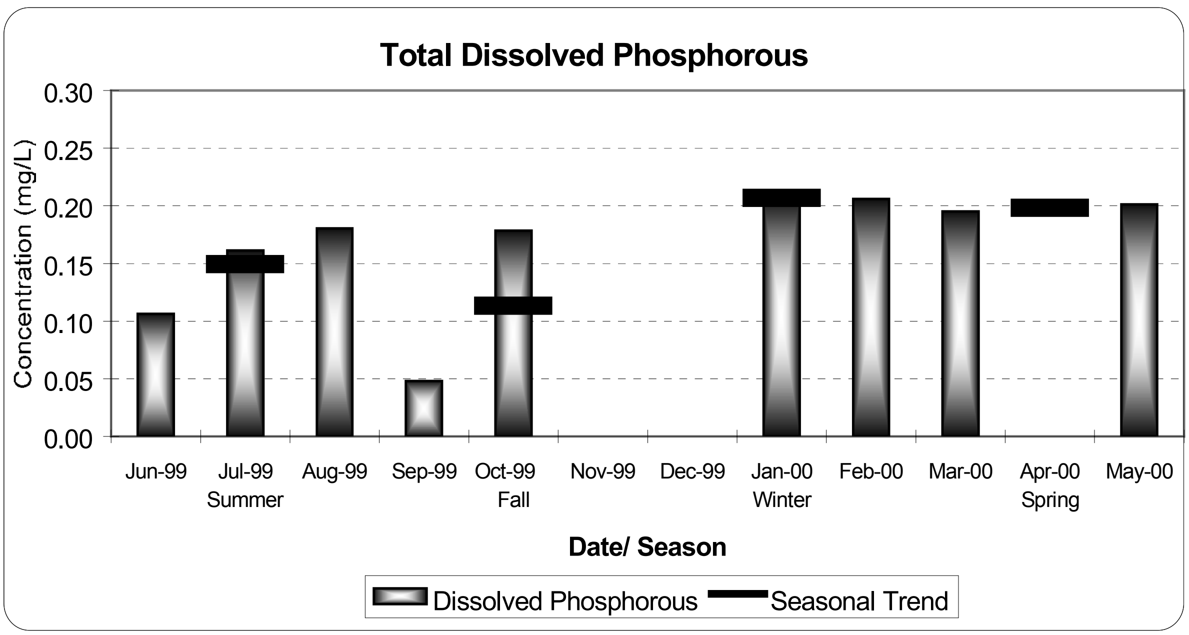


Figure 36. Inlake Monthly and Seasonal Dissolved Phosphorus for Cottonwood Lake

Figure 35 provides a comparison of suspended solids concentrations to the percentage of dissolved phosphorus in the total phosphorus load. Samples are organized by increasing suspended solids concentrations. A definite correlation between the two values is evident. The strong correlation between dissolved phosphorus and suspended sediments is indicative of algae populations that are not limited by phosphorus concentrations. This suggests a system that is not phosphorus limited.

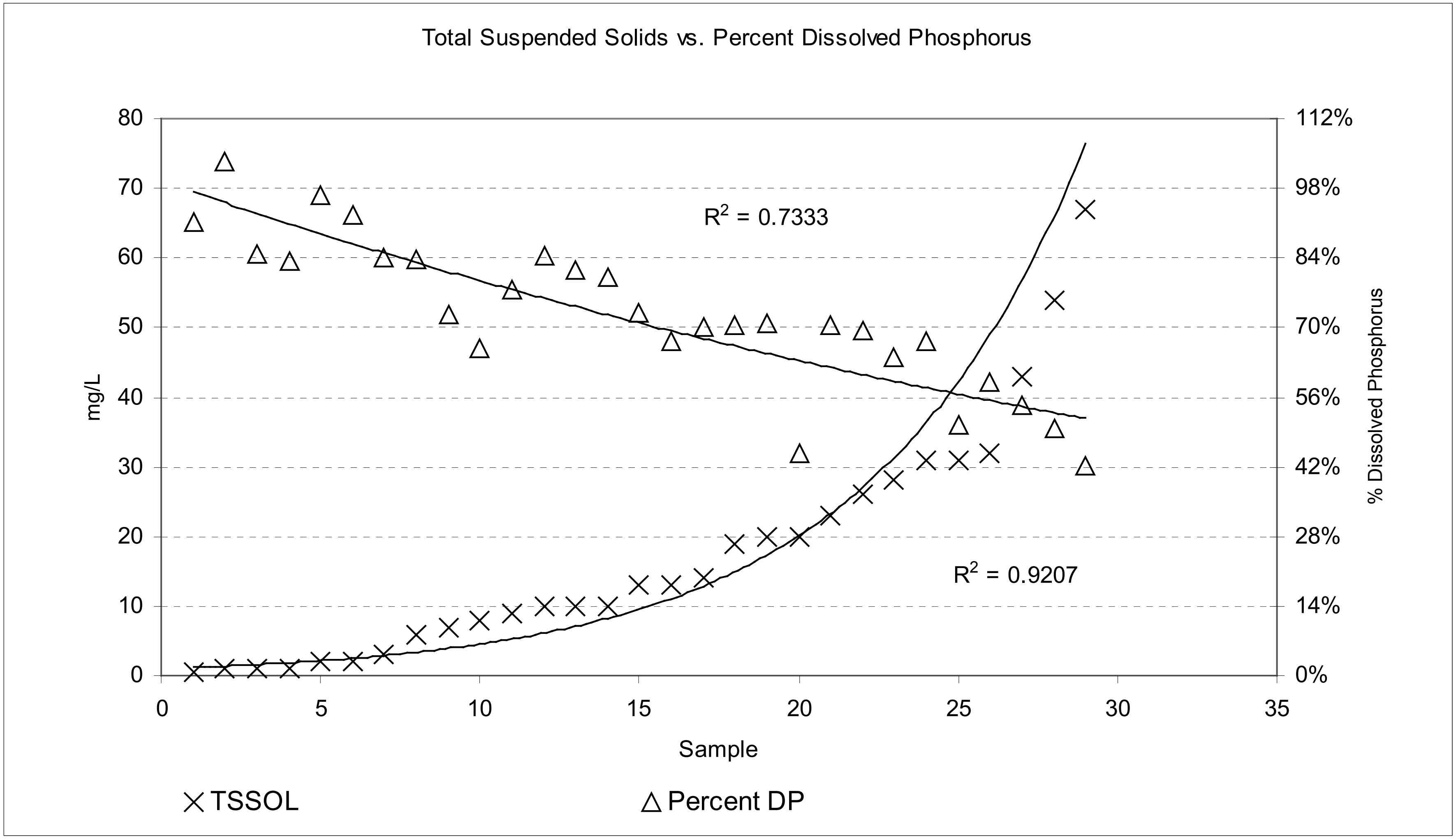


Figure 37. Comparison of Total Suspended Solids to Percentage Dissolved Phosphorus for Cottonwood Lake

Fecal Coliform Bacteria

Coliform bacteria are microbes commonly found in the environment. A more specific group of these microbes are fecal coliform bacteria, which grow in the intestines of warm-blooded animals and are found in their waste. Increased levels of human and livestock waste in water will result in greater levels of fecal coliform bacteria. Immersion recreation requires that no more than 400 colonies/100mL be taken in any one sample and that the mean for all samples be less than 200 colonies/100mL.

Samples taken at Cottonwood Lake were commonly below the detection limit of 10 colonies/100mL. The highest recorded level over the course of the project was 20 colonies/100mL on August 26, 1999. Those concentrations are all well within the state standards for the beneficial uses of Cottonwood Lake.

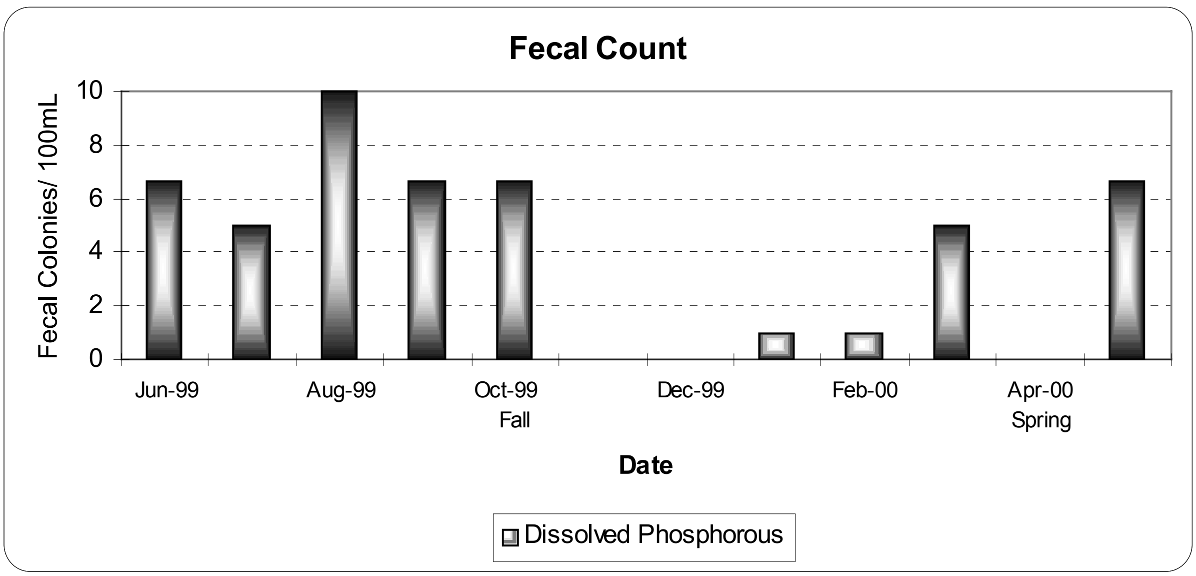


Figure 38. Inlake Average Monthly Fecal Coliform Counts for Cottonwood Lake

Chlorophyll-*a*

Chlorophyll-*a* is considered the principal variable to use as a trophic state indicator. There is a good correlation between planktonic primary production and algal biomass, and algal mass is an excellent trophic state indicator. Algal mass is also associated with the visible symptoms of eutrophication. Chlorophyll-*a* also affects the pH in lakes.

Algal blooms that occurred in late summer increased the chlorophyll *a* concentration with the month of August, 1999 experiencing the greatest concentrations. Concentrations were relatively low in winter and spring while summer and fall had the highest seasonal concentrations. The August sample data is based on a single sample from one site. Comparison of this data to the cells/mL recorded in the algae counts showed that this site had greater concentrations of algae than the other two sites. This is most likely due to wind and wave action forcing an accumulation of algae at one end of the lake. While additional samples may have reduced the average monthly concentration for August, it is likely that this month would have had the highest average concentration.

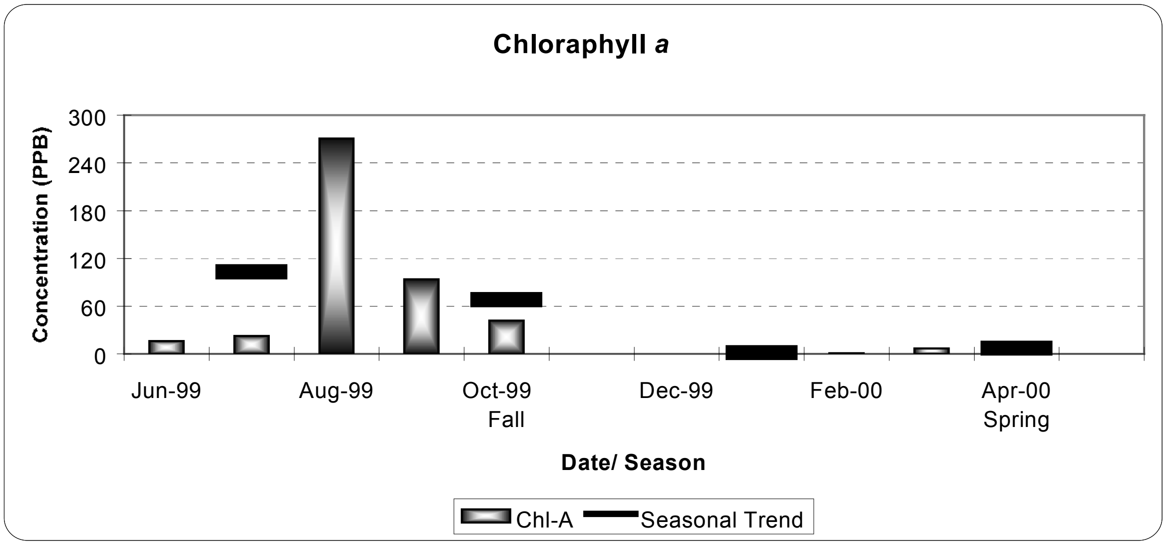


Figure 39. Inlake Monthly and Seasonal Chlorophyll *a* for Cottonwood Lake

The relationship between the chlorophyll-*a* and pH in Cottonwood Lake is shown in figure 38. As the chlorophyll-*a* concentration in the lake increases, the lake exhibits an alkaline shift in the pH. A reduction in algae blooms will result in lower concentrations of chlorophyll-*a*. Utilizing the equation in figure 38, a shift of 0.1 su of pH can be achieved with approximately 35 ppb of chlorophyll-*a*. While this is a small shift, it is significant enough to reduce the chance that the lake will exceed the maximum allowable pH of 9.00 su, thus protecting the beneficial uses.

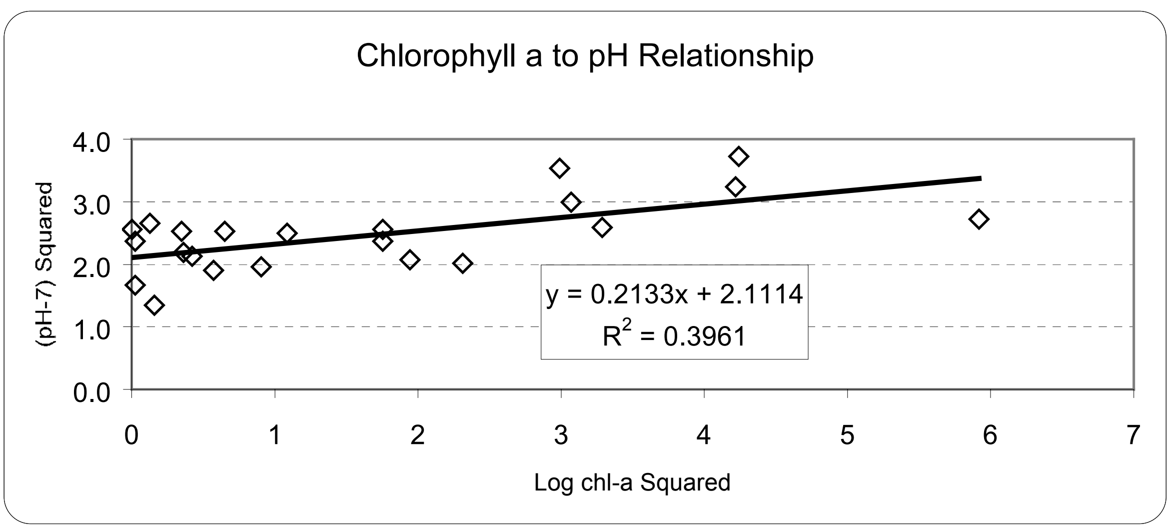


Figure 40. Chlorophyll *a* to pH Relationship for Cottonwood Lake

Phytoplankton

Planktonic algae collected monthly at three inlake sites in Cottonwood Lake (Figure 19) from June, 1999 to March, 2000, consisted of 69 taxa which represented 37 genera within seven algal phyla (Table 19). Diatoms (Bacillariophyceae) were the most diverse group with 36 taxa, followed distantly by green algae (Chlorophyta) with 17 taxa, and blue-green algae (Cyanophyta) represented by only 5 taxa. The remaining 11 identified taxa were distributed among four phyla of motile (flagellated) algae. Dinoflagellates (Pyrrhophyta), cryptomonads (Cryptophyta) and yellow-brown algae (Chrysophyta) were equally diverse but the euglenoids (Euglenophyta) contained only one taxon, *Euglena* sp.

The largest populations of motile cryptomonads, *Chroomonas* sp. Butcher 1967 (= *Rhodomonas minuta*), green flagellates (*Chlamydomonas* sp.), and yellow-brown algae (*Chromulina* sp.) and diatoms, were collected in March and blue-green algae (*Aphanizomenon* and *Microcystis* sp.) in the summer months. Diatoms were dominant in June 1999 and March 2000 (Figure 38 and 39). Blue-green algae (*Aphanizomenon)* were responsible for the August and September peaks in annual algal abundance (Figure 40). Blue-green algae and diatoms frequently dominate the algae communities of eutrophic hardwater lakes in the Midwest with green algae comprising a small percentage of the annual algae population (Prescott 1962).

Phytoplankton monthly density ranged from 827 cells/ml in February, 2000 to 225,950 cells/ml in August, 1999. Monthly biovolume ranged from 0.040 ul/l (= 40,000 um^3 x 10^{-6}) in February to 13.567 ul/l in August. Average monthly density and biovolume for the study period amounted to 76,477 cells/ml and 4.792 ul/l.

During this study, maximum algal densities were often observed at sites CL-2 and CL-3 and the smallest populations at site CL-1 (Figure 19). Algal minima (smallest of the three counts) were recorded at site CL-1 62% of the time and 38% at site CL-3. Occurrence of maximum densities was nearly equally distributed between site CL-2 and site CL-3 where maxima were recorded in 4 and 3 of 8 sampling dates, respectively. Mid-lake site CL-2 showed the least variation in algal numbers between dates. In contrast to the two other sites, minimum algae populations were never observed at site CL-2. The frequent occurrence of algal minima at site CL-1 and the overall distribution of algal numbers (especially buoyant blue-green algae) in Cottonwood Lake may have been greatly influenced by the preponderant direction of strong prevailing winds during the previous week or two prior to sampling (Small 1963). Wind induced water turbulence may also be a significant factor limiting algal growth in Cottonwood Lake due to the shallowness of the lake and the ease with which bottom sediments can be re-suspended to produce enough water turbidity that, at times, severely limits light penetration.

The initial algae samples for this survey were collected at the beginning of summer on June 23, 1999. Sample analysis for the three sites (Figure 19) indicated a mean population of 2,070 cells/ml. Individual site densities ranged from 445 cells/ml at site

CL-1 to 3,277 cells/ml at site CL-2. Those are rather low densities for early summer in a highly eutrophic lake and may have been partly due to normal seasonal succession (changeover) of algal species from coldwater spring forms to warmwater summer species. A major cause, as mentioned above, may have been water turbidity produced by strong wind/wave action stirring up shallow bottom sediments (Figure 28).

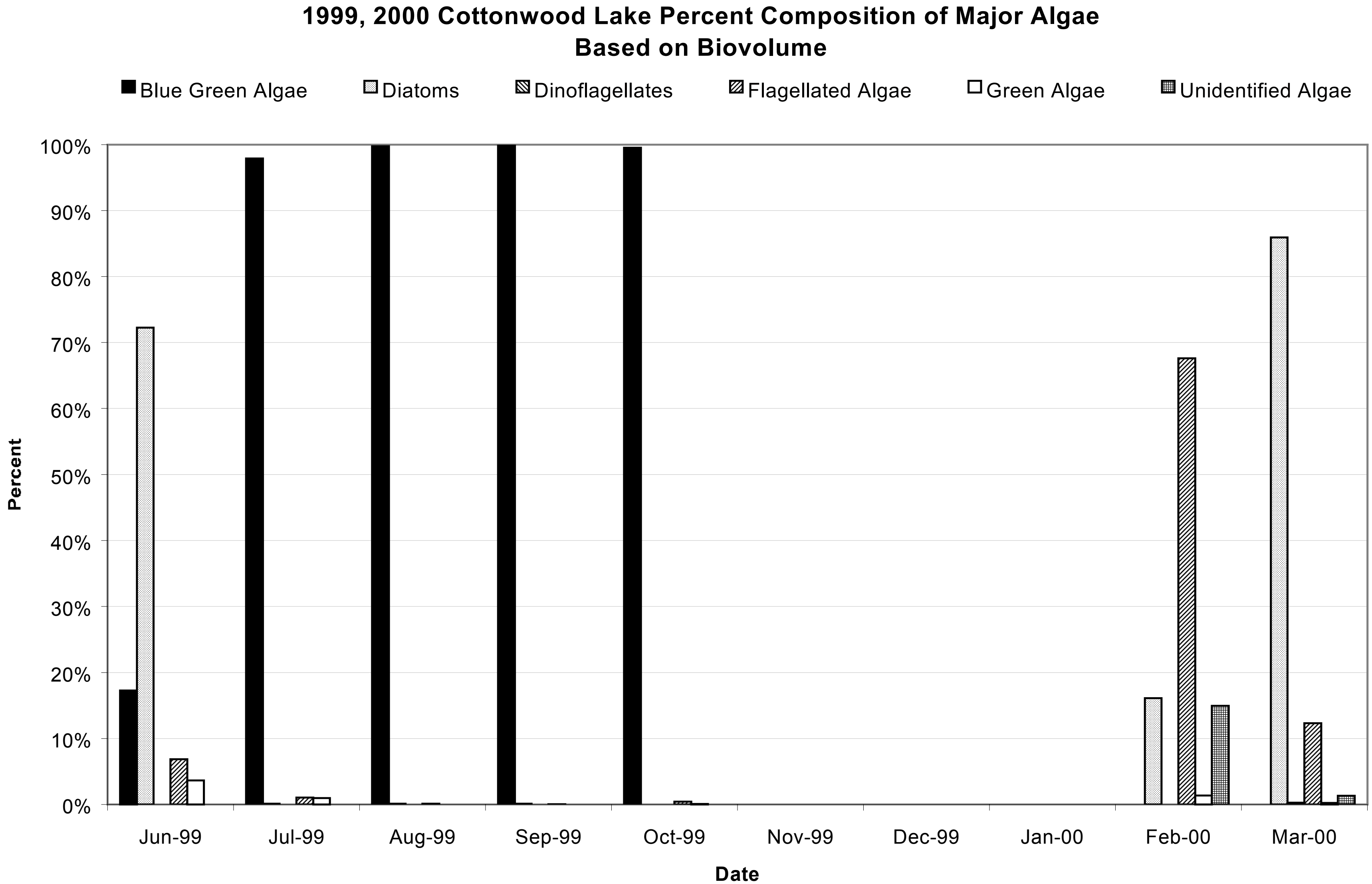


Figure 41. 1999, 2000 Cottonwood Lake Algae Percent Composition by Biovolume

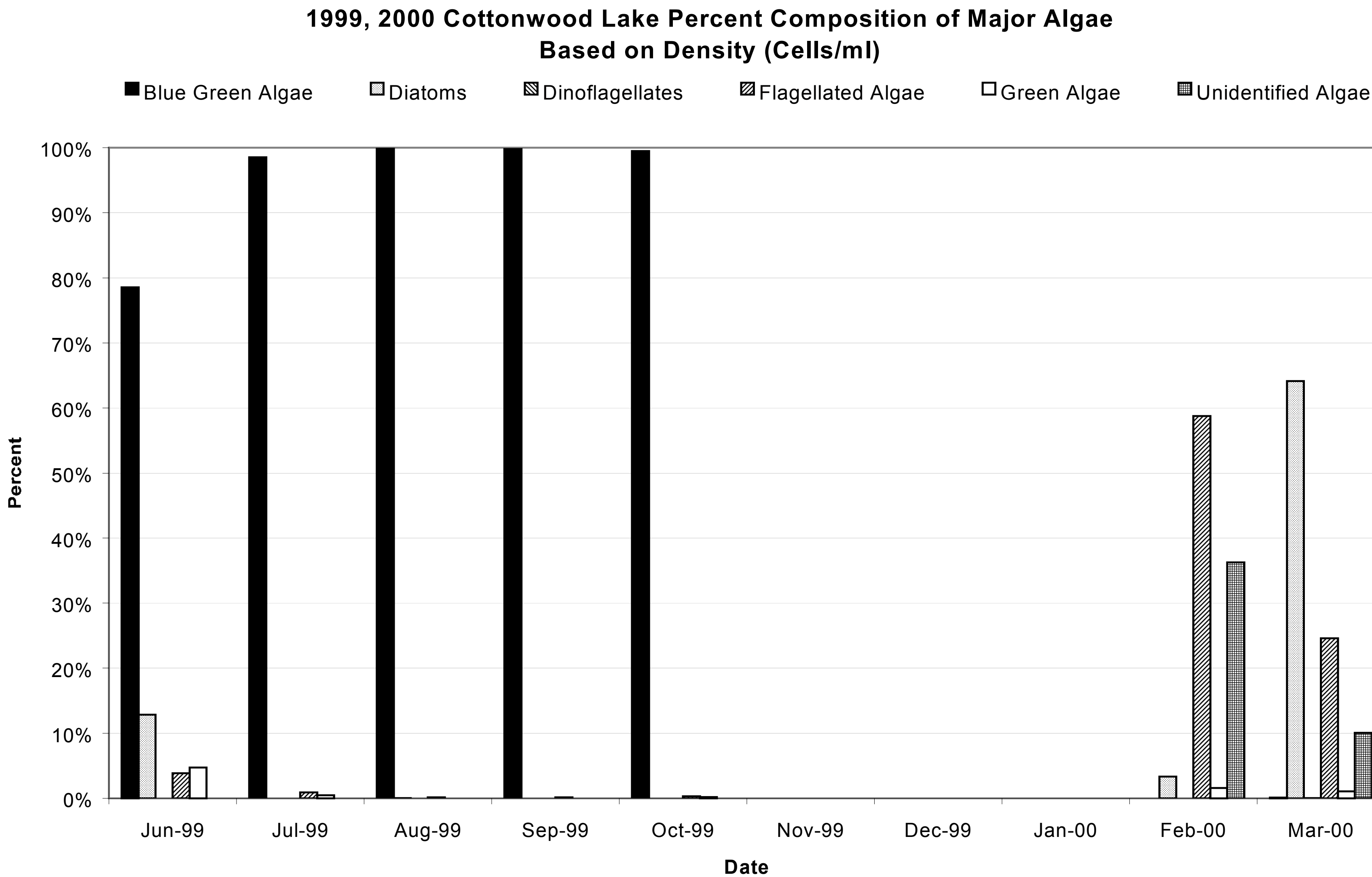


Figure 42. 1999, 2000 Cottonwood Lake Percent Composition of Algae (Cells/ml)

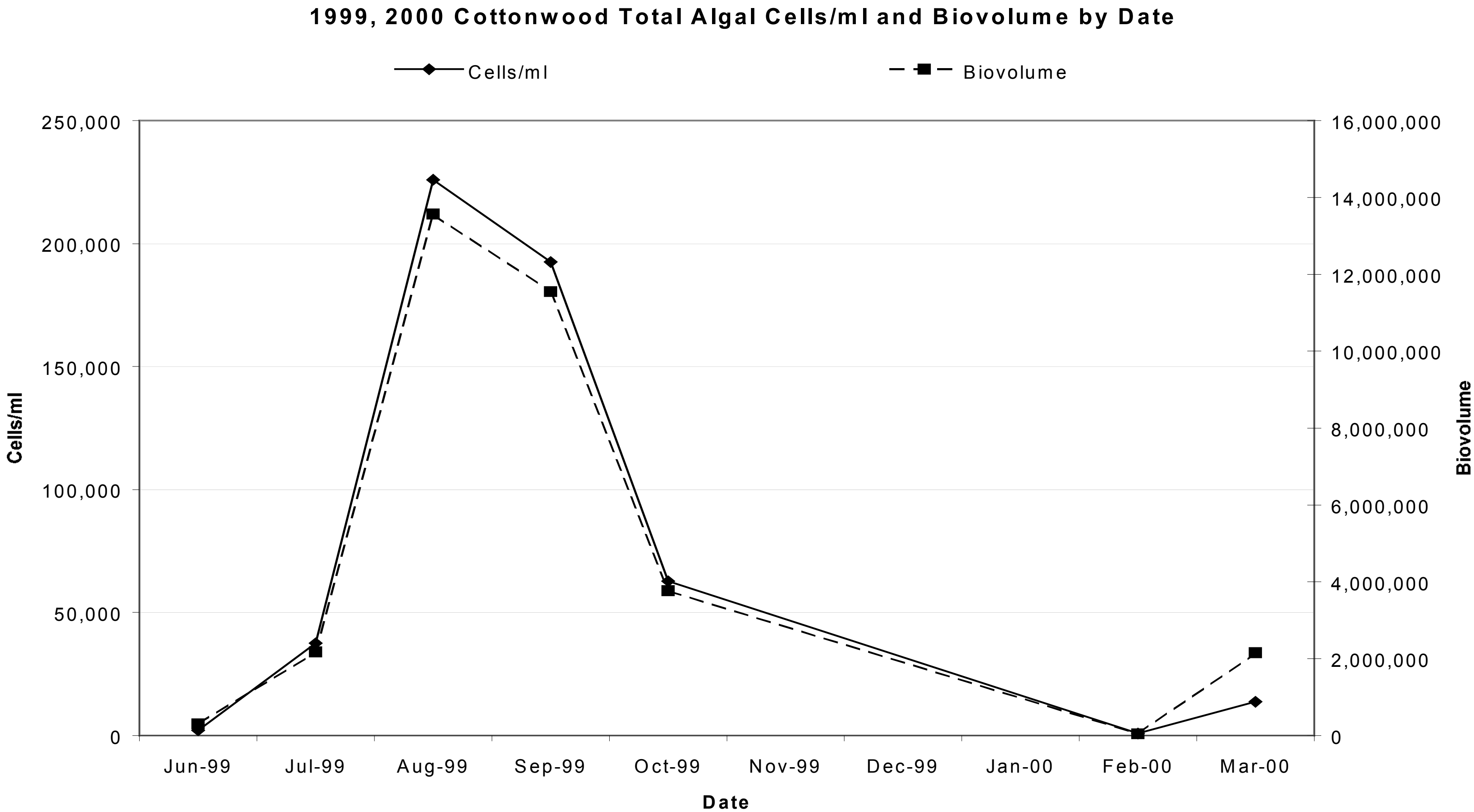


Figure 43. 1999, 2000 Cottonwood Total Algal Cells/ml and Biovolume by Date

Other than blue-greens, most other algal cells in the June samples appeared dead, moribund, or in poor condition, possibly, in part, because of the poor light conditions and suspended sediment mentioned above. Blue-greens do better under turbid conditions than other algae due to superior light capturing capabilities (Lee, 1999). Fifty-five percent of total algae in June consisted of the blue-green *Microcystis aeruginosa* which was present at a mean density of 1,548 cells/ml. Centric diatoms, primarily *Cyclotella meneghiniana*, composed 13% of the total, and non-motile green algae, 5%. Various flagellated algal taxa comprised 4% of the total algae community on June 22, 1999.

The next samples collected on July 7,1999, indicated an 18-fold increase in mean algal density to 37,484 cells/ml. Most of this increase was due to the first appearance of *Aphanizomenon flos-aquae* at a mean density of 33,739 cells/ml and to an increase in the average density of *Microcystis* to 3,206 cells/ml. Diatoms in early July declined to trace densities whereas the proportion of blue-greens in the algae population increased to 98%. Mean density of both green algae and flagellates increased from 99 cells/ml and 80 cells/ml, respectively, in June to 186 cells/ml and 322 cells/ml in July. But the percentage of the total algae for greens and flagellates declined to less than 1% for each group.

By late August, the next sampling date, *Aphanizomenon* increased nearly 7-fold to 225,607 cells/ml and numerically (as cells per ml) comprised 95% of total algae. This level of dominance was maintained through September and late October (99%) the last sampling date of 1999 (Appendix I). In August, the lake algae population attained a yearly maximum of 225,950 cells/ml due to high densities of *Aphanizomenon* at site CL-3 (Table 9). The density gradient in algal numbers between sites was particularly sharp in August, presumably due to persistent southerly or southwesterly summer winds blowing over the lake surface. Total algae densities ranged from 27,560 cells/ml at site CL-1 to 506,789 cells/ml at site CL-3 virtually all of which were composed of *Aphanizomenon* (Appendix I).

September algae (*Aphanizomenon*) densities were only 15% below August levels (Sept. mean: 192,490 cells/ml). Also similar was the low number of species noted for both months compared to the early summer period (Appendix I). A major difference, however, was a reversal in the direction of the August algae density gradient. Minimal algal populations on the September 29 sampling date were present at site CL-3 (63,006 cells/ml) and maximum densities of 383,671 cells/ml were recorded at site CL-1. The cause of the reversal may have been a corresponding shift in prevailing winds from southerly during August sampling to northerly or northeasterly in late September.

Mean algae density on the last sampling date for 1999, on October 26, fell to 62,767 cells/ml due mainly to a decline in *Aphanizomenon* to 62,441 cells/ml. The major reason for this decrease was the seasonal drop in water temperature. *Aphanizomenon* is known primarily as a summer (warm-water) species. The number of algal species sampled in October remained low, similar to that recorded for September and August (Appendix I). The smallest algae population for the sampling date was present at site CL-1 (13,224 cells/ml while the maximum algal density was recorded at site CL-3 (98,821cells/ml).

The first samples of the year 2000 were collected on February 1. Sample analysis indicated typically small winter algae populations under ice cover at the three sites (mean: 633 cells/ml). Algal densities were similar for all three sites. Flagellated (motile) algae comprised 62% of total algae. Principal motile species consisted of *Chroomonas* sp. (= *Rhodomonas minuta*), *Chromulina* sp., and unidentified miscellaneous flagellates (Tables 18-20). Because of the lack of water turbulence under ice cover, the predominance of motile species is typical in many winter lake algae communities.

The next series of samples taken on February 16, 2000 disclosed a moderate increase in the lake algae population to 1016 cells/ml. Late winter increases inlake populations are not unexpected due to increasing light intensity at this time which favors photosynthesis and growth of some cold water taxa despite the presence of ice cover. The same motile species recorded on February 1 made up 57% of total algae on February 16 (Appendix I). No other changes from the previous sampling date were noted except for a moderate increase in pennate diatoms, but numbers of diatoms remained low (47 cells/ml).

The last samples of this survey were collected on March 23, 2000. Sample analysis indicated a early spring bloom of a small centric diatom *Stephanodiscus hantzschii* (7-15 um) at an average density of 8,415 cells/ml which comprised 61% of the total algae in March. Similar spring blooms of *S. hantzschii* were recorded in recent years in Blue Dog Lake (1997) and Lake Mitchell (1994) although those blooms occurred a month later in late April. The spring diatom pulse in Cottonwood Lake may have taken place earlier due to the shallowness of this waterbody (rapid warming) and early breakup of ice cover due to the mild winter of 1999-2000.

Total algae density in late March averaged 13,747 cells/ml and ranged from 9,990 cells/ml at site CL-1 to 17,567 cells/ml at site CL-3. Other algae groups that were abundant in March included the flagellate genera *Chroomonas* sp.(= *Rhodomonas minuta*), *Chlamydomonas* sp., and *Chromulina* spp. In addition, the pennate diatom *Synedra rumpens* became relatively common, as well (Appendix I). Non-motile green algae were of little quantitative importance as on most previous sampling dates.

Table 19. Algae Taxa for Cottonwood Lake

Taxa	Algal Group	Taxa	Algal Group
Amphiprora paludosa	Diatom (pennate)	Nitzschia capitellata	Diatom (pennate)
Amphora ovalis	Diatom (pennate)	Nitzschia hungarica	Diatom (pennate)
Amphora perpusilla	Diatom (pennate)	Nitzschia linearis	Diatom (pennate)
Anabaena flos-aquae	Blue-Green Algae (filamentous)	Nitzschia paleacea	Diatom (pennate)
Ankistrodesmus falcatus	Non-Motile Green Algae (single)	Nitzschia reversa	Diatom (pennate)
Ankistrodesmus sp.	Non-Motile Green Algae (single)	Nitzschia sp.	Diatom (pennate)
Aphanizomenon flos-aquae	Blue-Green Algae (filamentous)	Nitzschia tryblionella	Diatom (pennate)
Asterionella formosa	Diatom (colonial, pennate)	Oocystis lacustris	Non-Motile Green Algae (colonial)
Carteria sp.	Flagellated Algae (green)	Oocystis pusilla	Non-Motile Green Algae (colonial)
Chlamydomonas sp.	Flagellated Algae (green)	Oocystis sp.	Non-Motile Green Algae (colonial)
Chromulina sp.	Flagellated Algae (single, yellow-brown)	Oscillatoria sp.	Blue Green Algae (filamentous)
Chroomonas sp.	Flagellated Algae	Pascheriella tetras	Flagellated Algae (green,colonial (4 cells))
Chrysochromulina sp.	Flagellated Algae (single, yellow-brown)	Platymonas elliptica	Flagellated Algae
Chrysococcus rufescens	Flagellated Algae (single, yellow-brown)	Rhodomonas minuta	Flagellated Algae
Cryptomonas erosa	Flagellated Algae	Rhoicosphenia curvata	Diatom (pennate)
Cryptomonas sp.	Flagellated Algae	Scenedesmus quadricauda	Non-Motile Green Algae (colonial)
Cyclotella meneghiniana	Diatom (centric)	Scenedesmus sp.	Non-Motile Green Algae (colonial)
Cyclotella pseudostelligera	Diatom (centric)	Schroederia judayi	Non-Motile GreenAlgae
Epithemia turgida	Diatom (pennate)	Selenastrum minutum	Non-Motile GreenAlgae
Euglena sp.	Flagellated Algae (green)	Sphaerocystis schroeteri	Non-Motile Green Algae (colonial)
Glenodinium gymnodinium	Flagellated Algae (dino)	Stephanodiscus astraea	Diatom (centric)
Glenodinium sp.	Flagellated Algae (dino)	Stephanodiscus astraea minutula	Diatom (centric)
Gomphonema olivaceum	Diatom (pennate)	Stephanodiscus hantzschii	Diatom (centric)
Gomphonema sp.	Diatom (pennate)	Stephanodiscus niagarae	Diatom (centric)
Kirchneriella obesa	Non-Motile Green Algae (single or colonial)	Stephanodiscus sp.	Diatom (centric)
Kirchneriella sp.	Non-Motile Green Algae (single or colonial)	Surirella ovalis	Diatoms (pennate)
Melosira granulata	Diatom (centric)-filamentous	Surirella ovata	Diatoms (pennate)
Microcystis aeruginosa	Blue-Green Algae (colonial)	Synedra acus	Diatoms (pennate)
Navicula capitata	Diatom (pennate)	Synedra rumpens	Diatoms (pennate)
Navicula cuspidata	Diatom (pennate)	Synedra rumpens v. familiaris	Diatoms (pennate)
Navicula graciloides	Diatom (pennate)	Tetrastrum staurogeniaeforme	Non-Motile Green Algae (colonial)
Navicula gregaria	Diatom (pennate)	Unidentified algae	Algae
Navicula sp.	Diatom (pennate)	Unidentified flagellates	Flagellated Algae
Nitzschia acicularis	Diatom (pennate)	Unidentified pennate diatoms	Diatom (pennate)
Nitzschia amphibia	Diatom (pennate)		
Species Count 69			

Trophic State

Trophic status relates to the degree of nutrient enrichment of a lake and its ability to produce aquatic macrophytes and algae. The most widely used and commonly accepted method for determining the trophic state of a lake is Carlson's Index (1977). It is based on Secchi depth, total phosphorus, and chlorophyll *a* in surface waters. The values for each of the aforementioned parameters are averaged to give the waterbodies trophic status index.

Lakes with values less than 35 are generally considered to be oligotrophic and contain very small amounts of nutrients, little plant life, and are generally very clear. Lakes that obtain a score of 35 to 50 are considered to be mesotrophic and have more nutrients and primary production than oligotrophic lakes. Eutrophic lakes have a score between 51 and 65 and are subject to algal blooms and have high primary production. Hyper-eutrophic lakes receive scores greater than 65 and are subject to frequent and massive blooms of algae that severely impair their beneficial use and aesthetic beauty.

Table 20. Trophic State Ranges

TROPHIC STATE	TSI NUMERIC RANGE
OLIGOTROPHIC	0-35
MESOTROPHIC	36-50
EUTROPHIC	51-64
HYPER-EUTROPHIC	65-100

Project sample data give Cottonwood Lake an average annual TSI value of 66.20, placing it slightly above the breaking point between hyper-eutrophic and eutrophic lakes. This value increased to 70.07 when winter sample data (collected through the ice) were removed. The TSI values are normally only calculated for the growing season. Cottonwood Lake is located in the Northern Glaciated Plains (a level III ecoregion). As determined in "Ecoregion Targeting for Impaired Lakes in South Dakota" (Stewart, 2000) lakes in this region should have a mean TSI value of 65.00 or less to fully support their beneficial uses. Partial support of these uses is reached at TSI values between 65.01 and 70.00. Lakes that do not support these uses have TSI values greater than 70.01. Cottonwood Lake is listed as a non-supporting lake in the report. Spring and summer TSI values for the project support this with scores of 72.21 and 71.85 respectively.

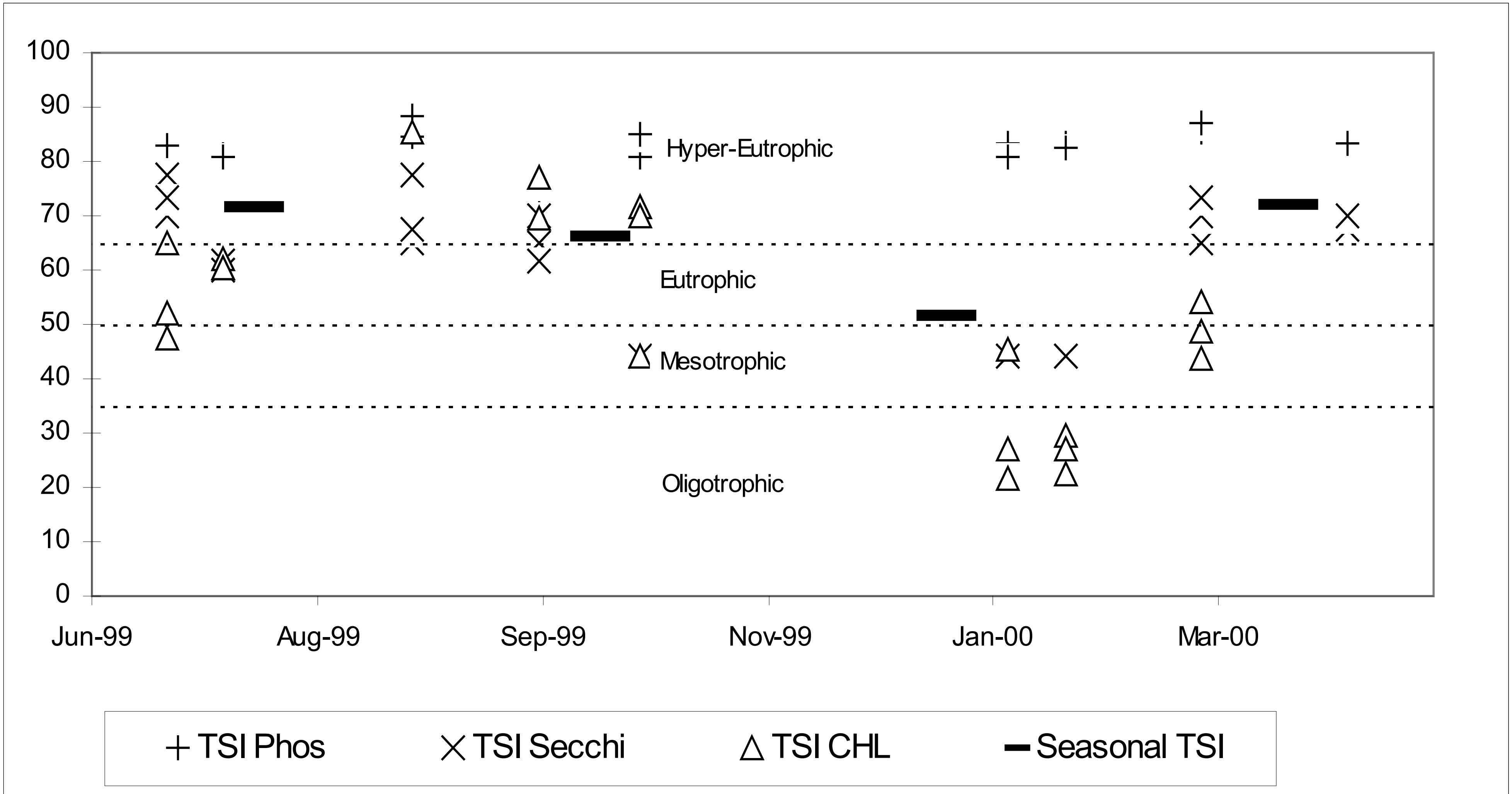


Figure 44. Monthly and Seasonal Trophic State for Cottonwood Lake

Long Term TSI Trends

The long-term TSI trend for Cottonwood Lake was last reported as increasing in the Statewide Lakes Assessment of 1996. With additional growing season data from 1999 and 2000 this trend line has shifted from a slightly increasing trend (slope .0012) to a slightly decreasing trend (slope -.6122).

There has been very little variation in Secchi and chlorophyll *a* trends. TSI Secchi trends have shifted to a slightly higher value, where as the TSI chlorophyll *a* values have shifted to slightly lower values nearly canceling each other out.

The major change that has occurred since the first samples in 1979 is a steady decrease in the total phosphorus concentration. The lower TSI values in 1999 and 2000 may be the direct result of several years of increased runoff. The years 1997 and 1998 were particularly wet years that may have flushed many nutrients out of the watershed and the lake.

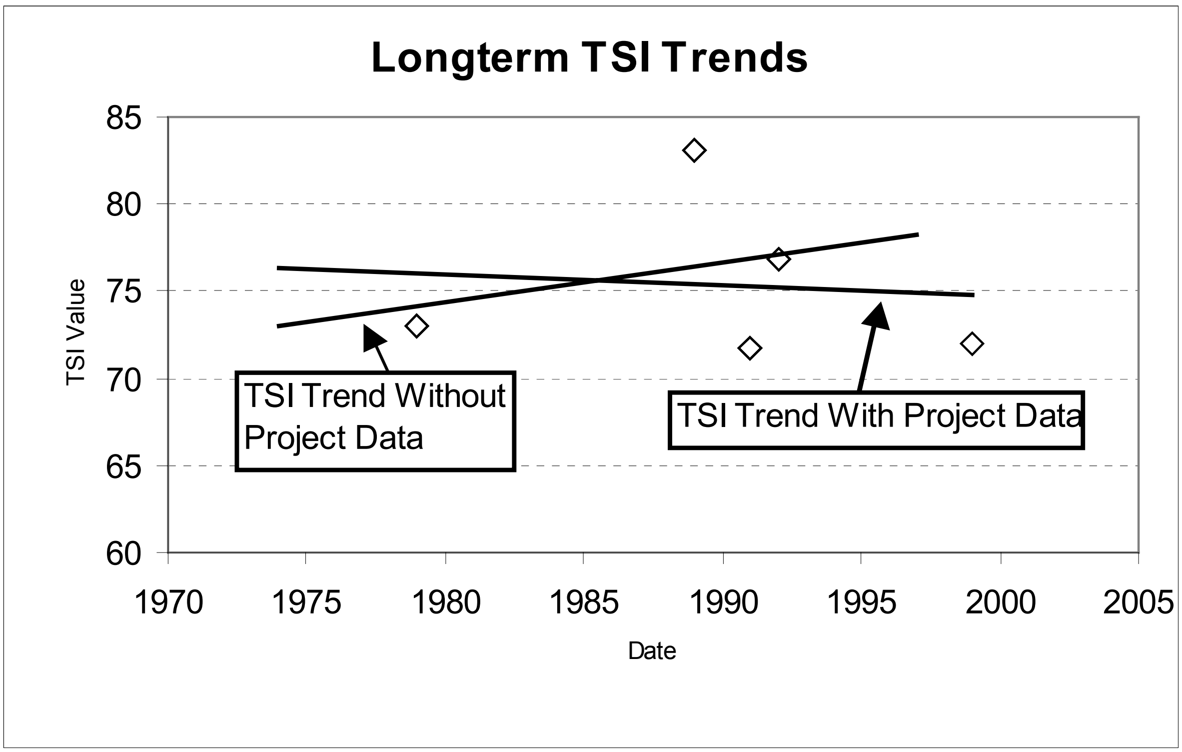


Figure 45. Long-term TSI Trends for Cottonwood Lake

Limiting Nutrients

Two primary nutrients are required for cellular growth in organisms, phosphorus and nitrogen. Nitrogen is difficult to limit in aquatic environments due to its highly soluble nature. Phosphorus loads are easier to control, making it the primary nutrient targeted for reduction when attempting to reduce lake eutrophication. The ideal ratio of nitrogen to phosphorus for aquatic plant growth is 10:1 (EPA, 1990). Ratios higher than 10:1 indicate a phosphorus-limited system. Those that are less than 10:1 represent nitrogen-limited systems.

The average for Cottonwood Lake was 10.7:1. October samples had the lowest phosphorus concentrations for the year placing those samples as phosphorus-limited. Treating these samples as outliers and removing them from the average results in a nitrogen-limited system with a ratio of 8.2:1. All but one of the remaining samples fell just below the ratio of 10:1 placing them in the nitrogen-limited category. Due to the close proximity of all the samples to phosphorus limitation, reductions of tributary loadings of this nutrient should produce a positive response in the trophic state of the lake.

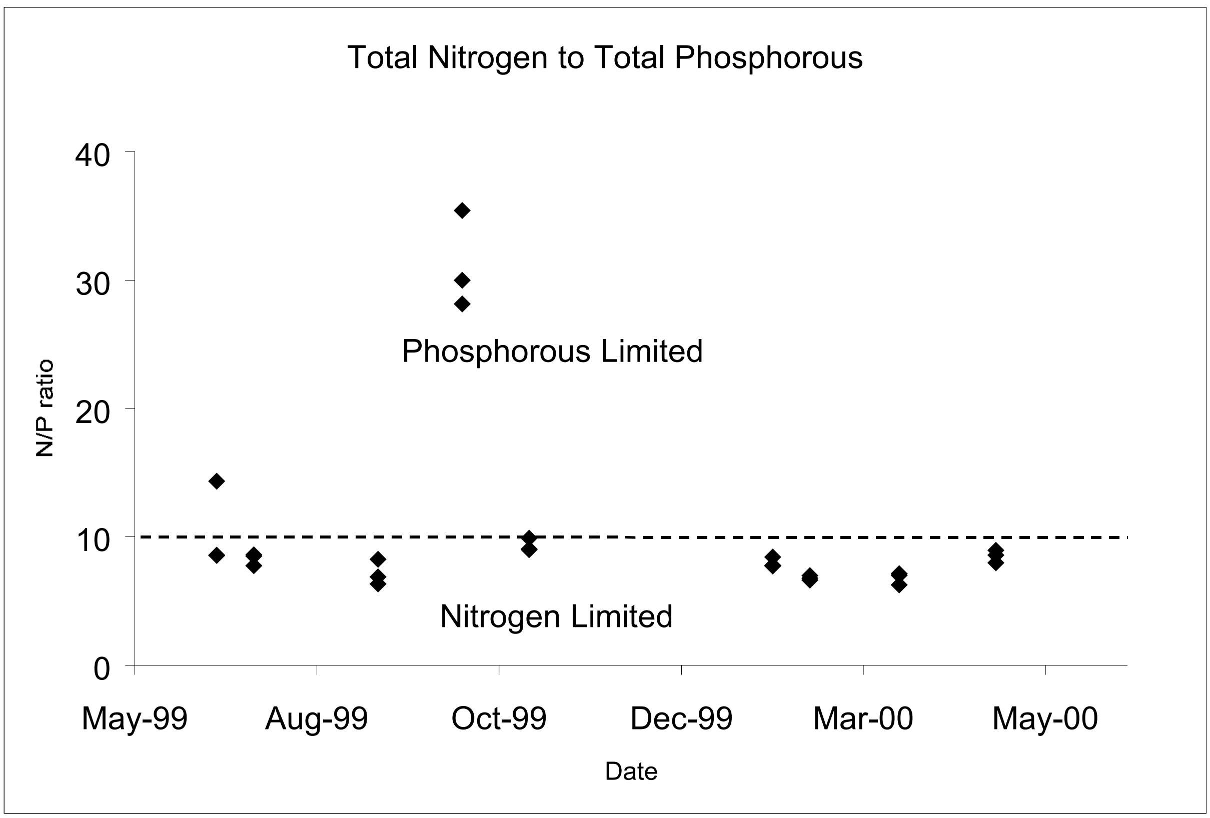


Figure 46 Nitrogen to Phosphorus Ratios for Cottonwood Lake

Caffeine Test

Caffeine is a chemical compound that does not naturally occur in South Dakota, and is found in many foods such as coffee, soda, tea, and chocolate. Testing for caffeine may indicate the presence of human waste in a water body. A total of 4 samples were sent in for analysis with a 5th sent as a blank to be used as a control.

The first sample was taken from the shallow bay located on the south end of the lake. The second sample was taken as a composite of the 3 inlake water quality sample sites. The third sample was taken as a composite of four locations along the east and west shores in front of the lakeside cabins. The fourth sample was taken from MC-6. This sample was taken to determine if caffeine loads from upper reaches of the watershed were impacting the levels in the lake.

Figure 44 shows the individual results from each of the samples. The average concentration for all of the samples from the lake was 0.0950 micrograms/liter. This yields approximately 1.26 kg of total caffeine in the lake, which is the equivalent of 580 gallons of brewed coffee (9,296-8 oz cups) or 2,140 gallons of Mountain Dew (22,827-12 oz. cans). The inlet to the lake and the blank sample produced no detectable levels of caffeine in either sample. While little information is available linking caffeine concentrations to waste loads or residence times, it is fairly safe to conclude that human waste is impacting Cottonwood Lake. The inlake loads of caffeine were taken into consideration when the septic loads for the lake were calculated.

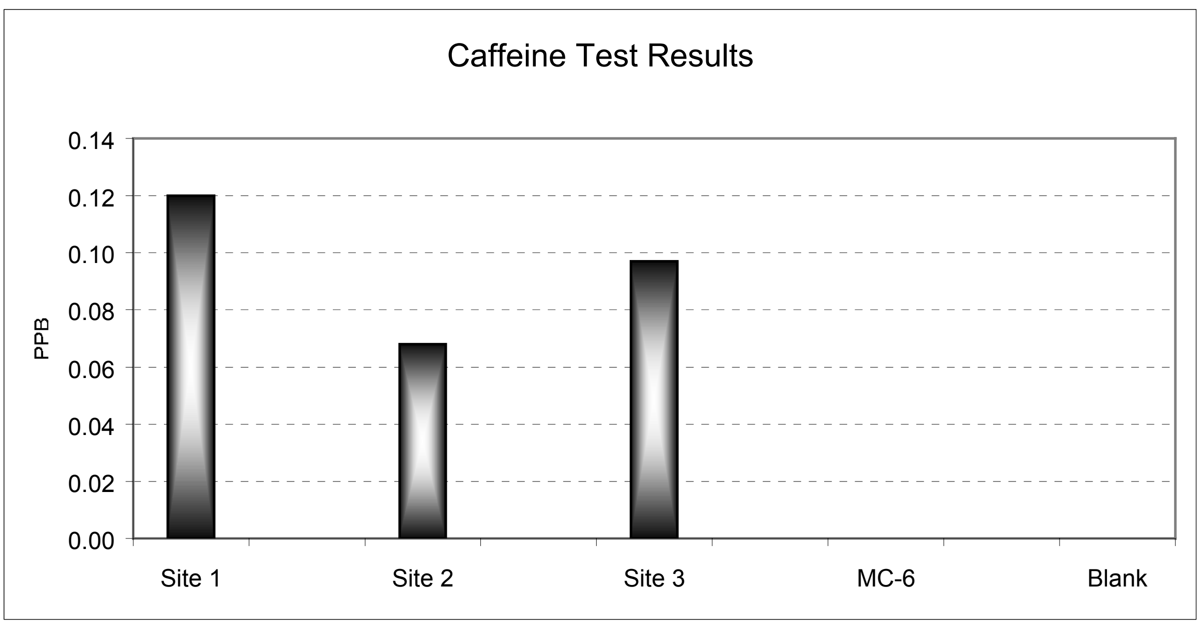


Figure 47. Caffeine Test Results for Cottonwood Lake

Reduction Response Modeling

Inlake reduction response modeling was calculated with BATHTUB, an Army Corps of Engineers Eutrophication Response Model (Walker, 1999). System responses were calculated using reductions in the loading of phosphorus to the lake from Medicine Creek and from the septic systems located at the lake. A detailed output from the BATHTUB model may be found in Appendix J. BATHTUB provides numerous models for the calculation of inlake concentrations of phosphorus, nitrogen, chlorophyll-*a*, and Secchi.

Loading data for Medicine Creek was taken directly from the results obtained from FLUX data. Atmospheric loads were provided by SDDENR. Groundwater loadings include the flowing wells and were calculated from samples taken from the wells. Estimated phosphorus loads (calculated in the Septic Survey section) from the cabins were included with the groundwater. Due to the high water table in the area, groundwater is the most likely transport mechanism for phosphorus to enter the lake from the septic systems.

Under current conditions, Cottonwood Lake is nitrogen-limited, and falls in the non-supporting category for its beneficial uses. Figure 45 depicts the resulting TSI values that correlate with the phosphorus load reductions. A 65% reduction in phosphorus loads from Medicine Creek along with a 100% reduction in septic system loads would be required to bring Cottonwood Lake to a condition in which it fully supports its beneficial uses as well as bringing it from a hyper-eutrophic condition to a eutrophic condition. A 65% reduction would be difficult at best to achieve. A more realistic 30% reduction from Medicine Creek in combination with a 50% reduction from septic systems will bring the lake to a phosphorus-limited state that partially supports its beneficial uses.

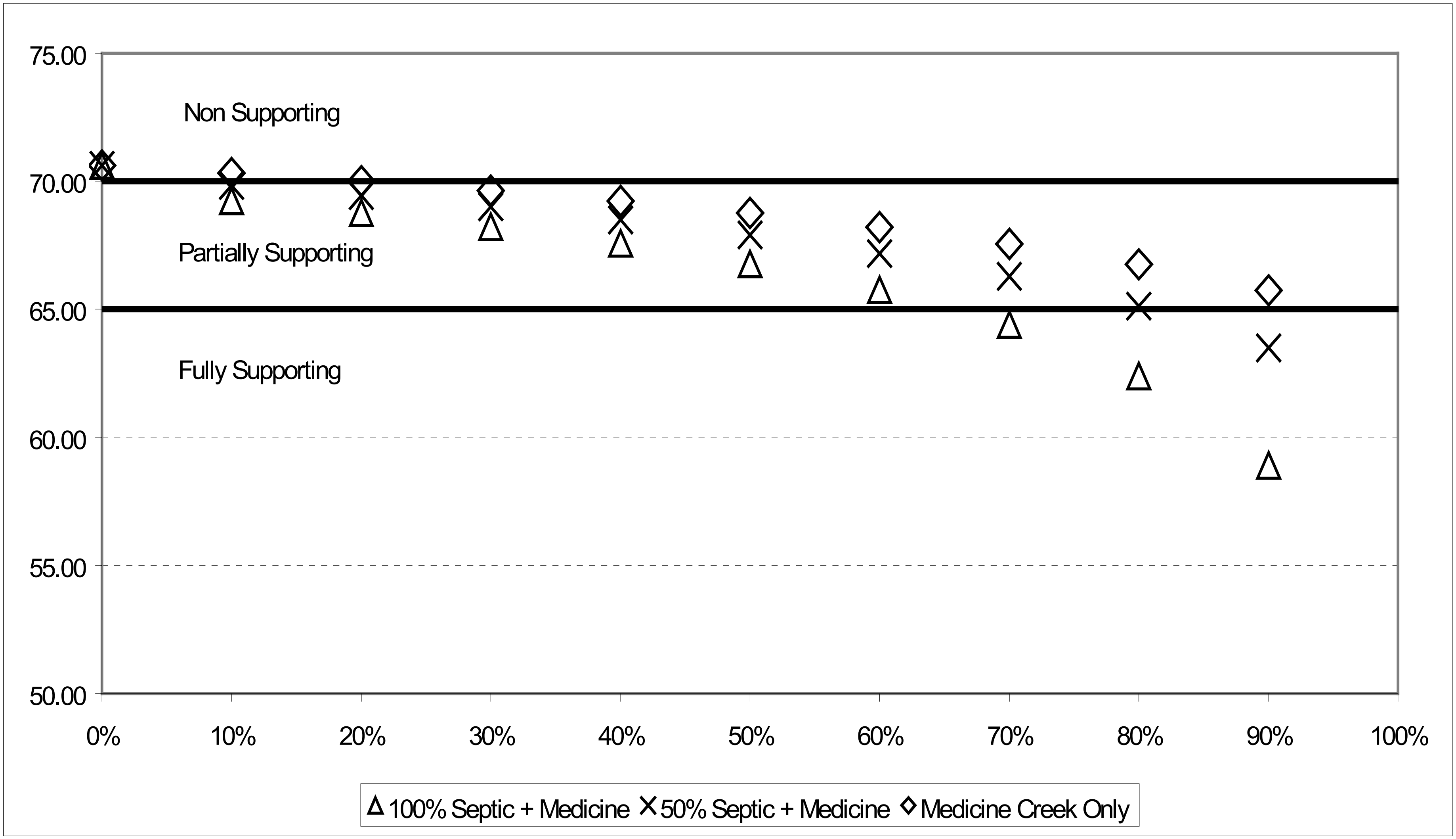


Figure 48. TSI Values with Phosphorus Load Reductions for Cottonwood Lake

Recommended Target Reductions

Watershed improvement efforts should target the reduction of phosphorus and sediments to Cottonwood Lake. Phosphorus and sediment reductions to the lake may be accomplished through several steps.

Improved management on at least 50% of the onsite wastewater disposal systems located along the shores of Cottonwood Lake will produce a 2% reduction in the total phosphorus load to the lake, while improved management on all of the systems will yield a 4% reduction in phosphorus loading.

Install 20 waste systems for the animal feeding operations that received AGNPS rankings of 34 or higher. Currently the highest-ranking AFO is in the permitting process and is having an Ag. Waste system installed. Management of this system along with 19 additional systems will reduce the phosphorus load to Cottonwood Lake by 34%.

Best management practices on 32,283 acres of rangeland will result in a 3% reduction in phosphorus and an 8% reduction in sediment as predicted by PSIAC. Best management practices on 10,541 acres of cropland will result in a 2% reduction in phosphorus and a 4% reduction in sediment as predicted by PSIAC. Range condition could be improved through planned grazing systems, water development, improving riparian and buffer zones, grass seeding, and tree planting (to facilitate changes in winter feeding areas). Cropland improvement may be accomplished by increasing crop residue through conservation and no till practices as well as improving riparian and buffer zones.

Slope cut-banks, along the lake, and establish communities of aquatic macrophytes along the portions of the shoreline that are exhibiting high amounts of erosion. Macrophytes will reduce the eroding effects of wave action that occur along this shoreline. Aquatic macrophytes will also help tie up ambient phosphorus concentrations in the lake, during periods of peak algae blooms. Reducing bank erosion will help eliminate a large portion of the 243 tons of sediment that are produced along the lake and discharged into the Turtle Creek watershed each year.

The combination of these restoration efforts will yield a 43% reduction in the total phosphorus load to Cottonwood Lake. Conservative estimates were used for the cabin loadings as well as the PSIAC reductions, providing for a margin of safety.

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Appendix A. Fisheries Report

SOUTH DAKOTA

FISHERIES

FILE COPY

STATEWIDE FISHERIES SURVEYS, 1997
SURVEY OF PUBLIC WATERS
Part 1
Lakes-Region IV

South Dakota
Department of
Game, Fish and Parks
Wildlife Division
Joe Foss Building
Pierre, South Dakota 57501-3182

Annual Report
No. 98-14

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-30

Name: Cottonwood Lake
County(ies): Spink County
Legal description: T115, R65, Sect. 4,5,7,8,9,17,18
Location from nearest town: 4 S, 6 W, 1 S, 1 mile W of Redfield
Dates of present survey: July 8-10, 1997
Date last surveyed: June 28-30, 1994
Management classification: Warm water marginal
Contour mapped: Y Date: 1964
Report prepared by: Charles Pyle
Scales read and digitized by: Randy Mount

PHYSICAL CHARACTERISTICS

Surface Area: 1650 acres; Watershed: 151,501 acres
Maximum depth: 7.5 feet; Mean depth: 6.5 feet
Lake elevation at survey (from known benchmark): Full feet

1. Describe ownership of lake and adjacent lakeshore property:

   Game, Fish and Parks, Fish and Wildlife Service as well as private landowners own adjacent property. The majority of the lakeshore is under private ownership.

2. Describe watershed condition and percentages of land use:

   The watershed is comprised equally of pasture and cropland.

3. Describe aquatic vegetative condition:

   Submergent and emergent vegetation are present, however emergent vegetation covers 80% of the shoreline.

4. Describe pollution problems:

   Cottonwood Lake is highly impacted by non-point source pollution. It is highly eutrophic and suffers from algae blooms, partial summer and winter-kills.

5. Condition of structures, i.e. spillway, boat ramps, etc.:

   The lake has two boat ramps that are in working condition.

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BIOLOGICAL DATA

Species encountered during lake surveys:

1. Yellow Perch (YEP)
2. Walleye (WAE)
3. Northern Pike (NOP)
4. Black Crappie (BLC)
5. Common Carp (COC)
6. Black Bullhead (BLB)

Methods:

Cottonwood lake was sampled July 8-10, 1997. A total of six gill net and sixteen frame net sets were utilized. Nets were fished for a twenty-four hour period and reset. Experimental monofilament gill nets were 45.7 m (150ft) by 1.8 m (6 ft). Gill nets had six 7.6 m (25 ft) panels of 1.3 cm 1/2 in), 1.9 cm (3/4 in), 2.5 cm (1 in), 3.2 cm (1 1/4 in), and 5.1 cm (2 in) bar mesh. Trap nets had double frames of 1.5 m x 1.3 m (3 ft x 5 ft) and 1.9 cm (3/4 in) mesh. Nets that were collapsed or had been tampered with were disregarded. Scales from walleye were taken from behind the left pectoral fin, below the lateral line. Scales were analyzed using DisBcal software and imported into PC Minnow. One hundred lengths (mm) and fifty weights (g) were taken when sample size allowed. Catch-per-unit-effort (CPUE), proportional stock density, relative stock density-preferred (RSDP) and relative weight (Wr) were calculated using PC Minnow (Tables 1&2). Fish that were counted but not measured were assigned to length groups based upon distribution of the one hundred fish sub-sample. The PC minnow was utilized to calculate common fisheries indices.

Results and Discussion :

Black Bullhead and Common Carp

During the 1997 survey, black bullhead population comprised 96% of frame net catch and had a CPUE of 346.9 (Table 1). Gill net CPUE of 73.0 also exhibits the abundant population (Table 2). Lengths ranged from 11-26 cm with the majority divided between 13-16 cm and 20-23 cm (Figure 2). Frame net PSD has decreased from 41 to 20 (Table 1). Common Carp CPUE has decreased compared to 1994. Although, the abundance of carp is relatively high compared to other fish populations in the lake. Commercial harvesting should be economically feasible on these two species.

Black Crappie

Frame net CPUE has consistently indicated low abundance of black crappie since 1990. However, 1997 produced the highest CPUE of 2.61 and lengths from 19-29 cm. The population mainly consisted of individuals of 22 cm and larger (Figure 1), resulting in PSD of 98 and RSDP of 57. All length groups had high Wr values and all were in good

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condition. Again, an increase in water levels may have been beneficial to the population. Large size may make this population appealing to anglers despite low abundance.

Yellow Perch

Yellow perch gill net CPUE has increased from 9.7 to 17.67 since 1994. Length frequency (figure 3) shows fish from 13 to 31 cm indicating stable recruitment. Yellow perch conditions were found to be good with most length categories having Wr values between 107 - 112 (Table 4.). PSD and RSDP values of the 106 fish gill net sample were 74 and 24 (Table 1). An increase in water levels within the past three years may contribute to the increased populations.

Walleye and Northern Pike

Walleye and northern pike are found in low abundance and both species gill net CPUE declined compared to 1994. All but three of the walleyes sampled were age 2 (Table 5). Walleye lengths ranged from 25 to 41 cm sampled by both gears. Northern pike consisted of lengths from 19 to 77 cm with most found between 23 to 27 cm. Northern pike sampled were found in good condition with Wr in 90's (Table 4).

Recommendations:

1. Commercial fishing efforts should be encouraged for black bullhead and common carp.

2. Manage primarily as walleye and yellow perch fishery. Continue walleye stockings and direct habitat development towards these species if feasible.

Table 1. Catch and partial analysis of eighteen frame net sets in Cottonwood Lake (Spink Co.), July 8-10, 1997.

Species	N	% Comp	CPUE (80%C.I.)	1994CPUE(80%C.I.)	PSD (90%C.I.)	RSDP (90%C.I.)
COC	136	2.1	7.56+-2.87	47.9+-17.2	96 (93 , 99)	51 (44 , 59)
BLB	6242	96.3	346.78+-127.36	15.3+-7.0	20 (19 , 21)	-
NOP	20	0.31	1.11+-0.44	1.0+-0.6	50 (30 , 70)	25 (8 , 42)
BLC	47	0.72	2.61+-1.00	0.5+-0.3	98 (94 , 100)	57 (45 , 70)
YEP	27	0.41	1.50+-0.47	0.1+-0.1	63 (47 , 79)	4 (0 , 10)
WAE	11	0.16	0.61+-0.39	0.6+-0.4	9 (0 , 26)	-

* 90% Confidence Interval (lower, upper)

000162

Table 2. Catch and partial analysis of six gill net sets in Cottonwood Lake (Spink Co.), July 8-10, 1997.

Species	N	% Comp	CPUE (80%C.I.)	1994 CPUE 80%C.I,)	PSD (90%C.I.)	RSDP (90%C.I.)
COC	21	3.65	3.50+-1.31	16.0+-6.6	95 (87 , 100)	14 (1 , 28)
BLB	438	76.0	73.0+-19.3	18.7+-6.0	26 (22 , 29)	-
NOP	4	0.69	0.67+-0.49	1.0+-0.5	-	-
YEP	106	18.4	17.67+-7.87	9.7+-1.3	74 (66 , 81)	24 (17 , 30)
WAE	7	1.23	1.17+-0.71	5.5+-1.9	-	-

* 90% Confidence Interval (lower, upper)

Table 3. Weighted mean Wr by length category for frame net samples for selected species collected in Cottonwood Lake (Spink Co.), July 8-10, 1997.

Species	NOP(n)	BLC(n)	YEP(n)	WAE(n)
<S	-	-	-	-
S	89(19)	103(47)	104(27)	93(11)
S-Q	89(9)	103(1)	105(10)	93(10)
Q-P	86(5)	106(19)	104(16)	90(1)
P-M	88(3)	101(27)	-	-
M-T	92(2)	-	95(1)	-

Table 4. Weighted mean Wr by length category for gill net samples for selected species collected in Cottonwood Lake (Spink Co.), July 8-10, 1997.

Species	NOP(n)	YEP(n)	WAE(n)
<S	96(1)	-	-
S	94(3)	109(106)	95(7)
S-Q	99(1)	112(28)	96(5)
Q-P	91(1)	109(53)	90(2)
P-M	90(1)	107(23)	-
M-T	-	93(2)	-

Table 5. Average back-calculated lengths (mm) for each age class of walleye sampled with both, frame and gill net in Cottonwood Lake (Spink Co.), July 8-10, 1997.

Year Class	Age	N	1	2	3
1996	1	1	194		
1995	2	15	166	277	
1994	3	2	168	291	356
Mean			168	296	356
N		18	18	17	2

Table 6. Stocking record for Cottonwood Lake (Spink Co.), July 8-10, 1997.

Species	**Size**	**Number**	**Year**
WAE	FRY	700,000	1983
YEP	FGL	20,000	1983
WAE	FRY	1,600,00	1984
YEP	FGL	47,200	1984
WAE	FRY	1,650,00	1985
WAE	FRY	800,000	1986
WAE	FRY	800,000	1987
WAE	FRY	765,000	1989
WAE	FRY	800,000	1991
SMB	MFG	20,000	1992
SMB	MFG	13,000	1992
WAE	FRY	1,600,00	1992
SXW	FRY	539,000	1993
SXW	FRY	261,000	1993
SMB	MFG	16,000	1993
WAE	FRY	3,400,00	1995
WAE	FRY	1,600,00	1997

000164

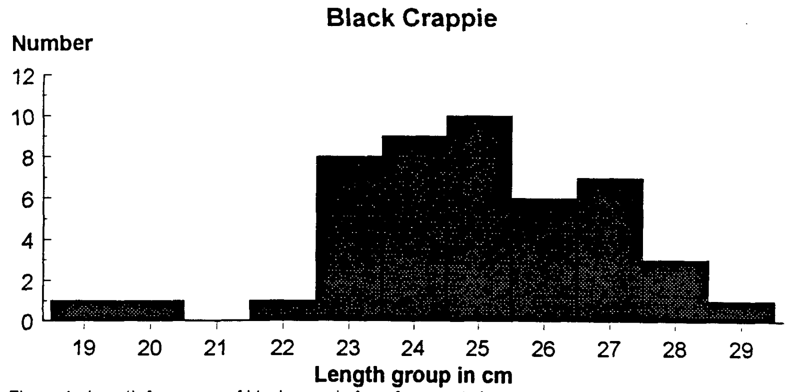


Figure 1. Length frequency of black crappie from frame nets in Cottonwood Lake, 1997.

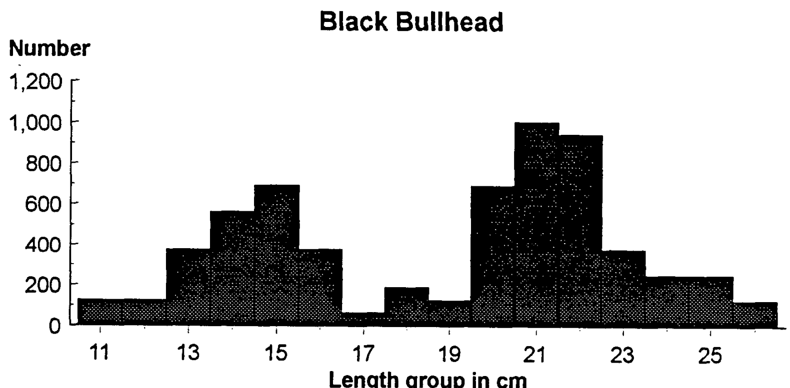


Figure 2. Length frequency of black bullhead from frame nets in Cottonwood Lake, 1997

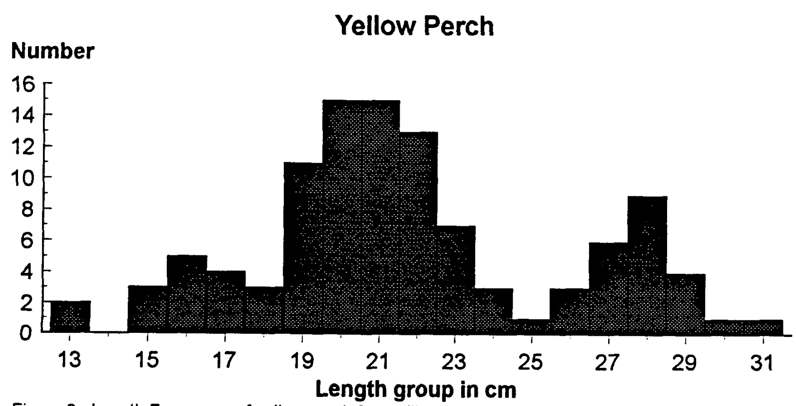
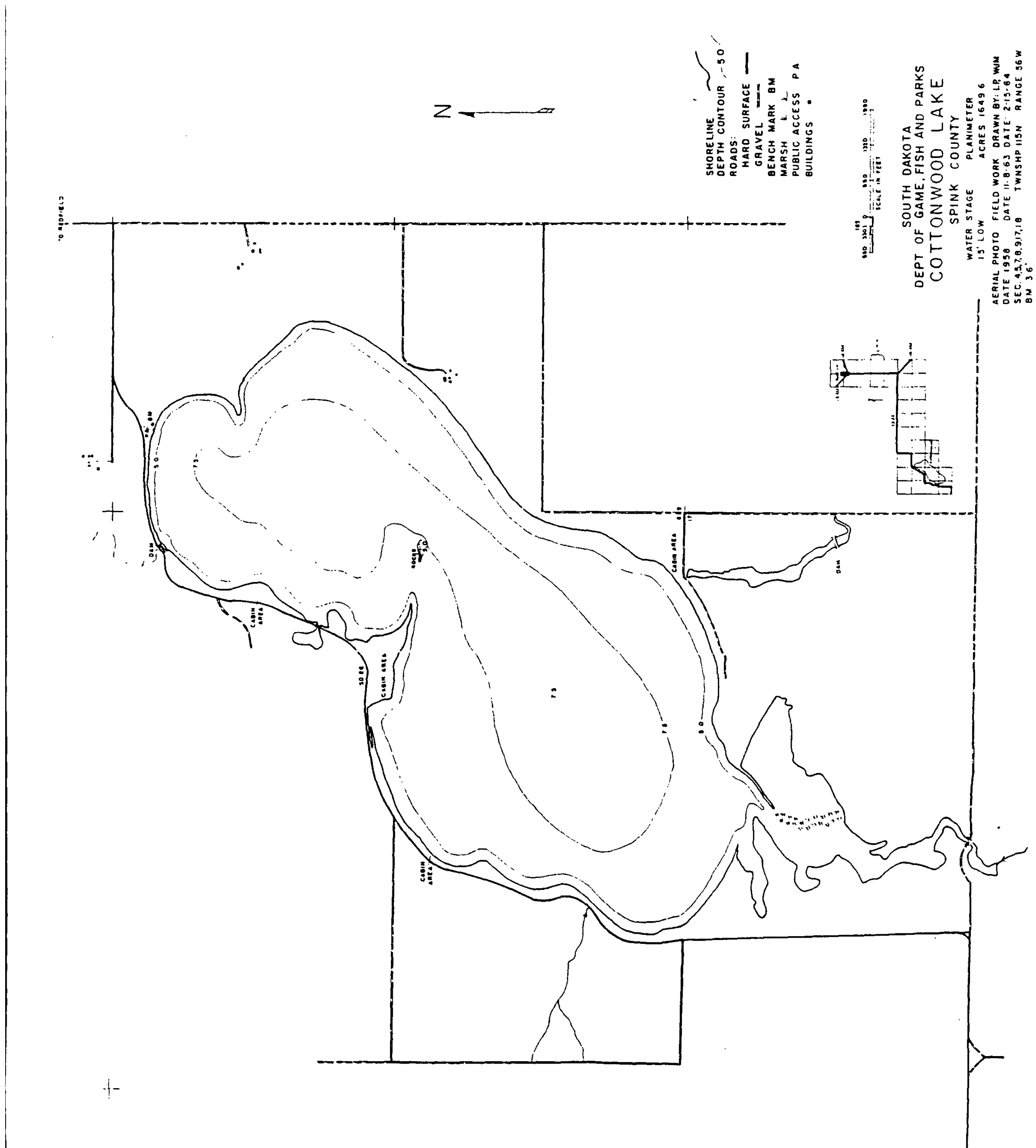


Figure 3. Length Frequency of yellow perch from gill nets in Cottonwood Lake, 1997.

000165

Figure 4.


SHORELINE
DEPTH CONTOUR
ROADS: HARD SURFACE
GRAVEL
BENCH MARK BM
MARSH
PUBLIC ACCESS PA
BUILDINGS
SOUTH DAKOTA
DEPT OF GAME, FISH AND PARKS
COTTONWOOD LAKE
SPINK COUNTY
CABIN AREA
N

Appendix B. PSIAC Report

SEDIMENT ASSESSMENT AND EVALUATION STUDY

FOR

LAKE LOUISE AND COTTONWOOD LAKE

HAND, HYDE, FAULK, AND SPINK COUNTIES SOUTH DAKOTA

United States Department of Agriculture
Natural Resources Conservation Service
South Dakota

In Cooperation with

South Dakota Department of Environment and Natural Resources
And
Hand County Conservation District

MAY 2000

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INTRODUCTION

The Lake Louise – Cottonwood Lake Watershed Assessment Project is the initial phase of a proposed watershed-wide restoration project. Agricultural non-point source pollution, specifically sediment and nutrients, have been identified as sources of water quality impairment in the watersheds of Lake Louise and Cottonwood Lake. The South Dakota Department of Environment and Natural Resources (DENR) has previously relied on computer simulation to analyze non-point source pollution in agricultural watersheds. In South Dakota the most commonly used tool to assess agricultural non-point sources of pollution has been the Agricultural Nonpoint Source (AGNPS) model. AGNPS results have proved to be useful in watersheds that are predominantly cropland, however, it is not well adapted for evaluating watersheds that are primarily rangeland, hayland and/or pastureland.

Rangeland, hayland, and pastureland account for approximately 70 percent of the total land use in the study area. The Pacific Southwest Interagency Committee (PSIAC) sediment evaluation method was determined to be the most effective tool to use in an effort to determine total sediment loads and the sediment contributions from each of the different agricultural land uses. PSIAC is presently the only method available that is recognized as an evaluation tool capable of assessing sediment loads from watersheds with a large percentage of rangeland.

Phosphorus evaluations have been based on water quality monitoring data that was collected during the 1999 water year. Total and dissolved phosphorus loads were measured at various points throughout the Lake Louise and Cottonwood Lake watersheds, at the point of discharge into the lakes, and at the outlet of the lakes. The values for the dissolved fraction of the total phosphorus delivered to Lake Louise and Cottonwood Lake were 64 percent of the total phosphorus and 87 percent of the total phosphorus respectively. The remaining portions of the total phosphorus loads would be considered attached or sediment associated. The values for the attached portion of the phosphorus concentrations were compared to the PSIAC sediment values. The phosphorus concentrations associated with sediment were based on an average of the chemical analyses of phosphorus concentrations found in the major soil associations.

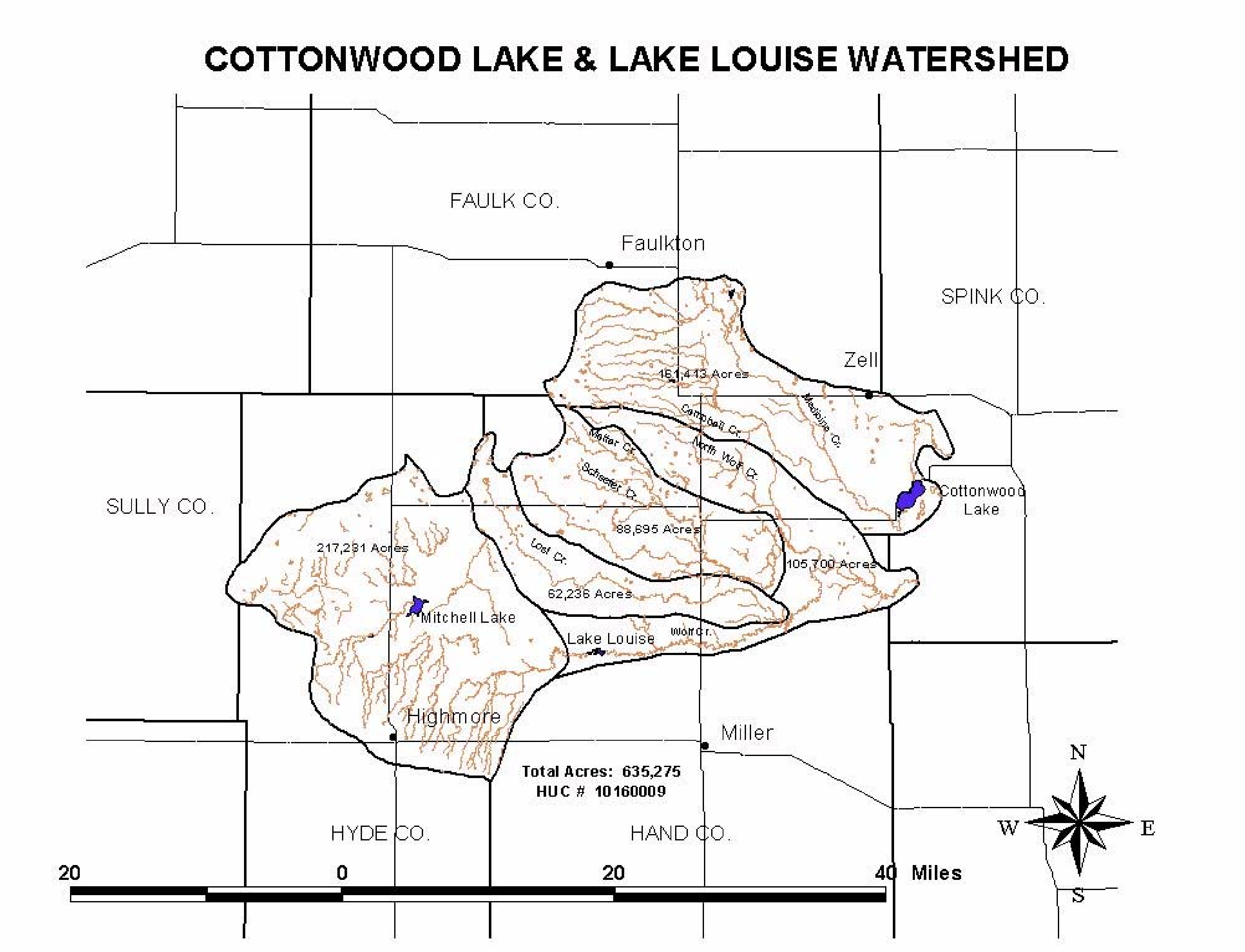
Phosphorus fertilization is not a common practice in the study area and was determined to be insignificant when compared to the naturally occurring phosphorus concentrations in the soil. The ratio of dissolved phosphorus to total phosphorus indicates that sediment associated phosphorus is not the major source of the phosphorus reaching the lakes. Further assessment of the watersheds is needed to identify other possible sources of phosphorus.

PROJECT SETTING

The Lake Louise — Cottonwood Lake Watershed Assessment study area is located in central South Dakota (Figure 1) and is part of the James River Lowlands in the Central Lowland physiographic division. The Central Lowlands region in eastern South Dakota is an area profoundly influenced by the most recent glaciation. Natural drainage systems are poorly developed, and numerous lakes and wetlands occur on the landscape. The large number of “pothole” wetlands typical of the Prairie Pothole Region characterizes the northeastern part of South Dakota. The study area is located in the western extent of this region. Typically, major streams flow from north to south. Very flat slopes characterize the low-lying areas of the James River Lowland.

The study area is located in two Major Land Resource Areas (MLRA) 53C and 55C. The Watershed Assessment project covers 635,275 acres of drainage area in four counties, Hand, Hyde, Faulk, and Spink (Figure 1). Lake Louise is located in Hand County and Cottonwood Lake is located in Spink County, South Dakota. The sediment and nutrient loads from agricultural non-point sources in the study area have been identified as the major sources contributing to the impairment of the designated beneficial uses of the lakes.

FIGURE 1



WATERSHED ASSESSMENT

The Lake Louise and Cottonwood Lake Watershed Assessment study area was divided into sub-watersheds to determine relative contributions of sediment delivered from each area. Five sub-watersheds were identified and named for the major tributary stream in the respective 11-digit hydrologic unit (Figure 1). Water quality samples were collected in only the Medicine Creek (Cottonwood Lake) and Upper Wolf Creek (Lake Louise) sub-watersheds. The sub-watershed boundaries and acreage were determined using existing Geographic Information System (GIS) data (Table 1).

Medicine Creek drains the 161,413-acre Cottonwood Lake watershed. The creek begins in Faulk County, travels east through the northeast part of Hand County and discharges into Cottonwood Lake in Spink County. The Cottonwood Lake watershed includes 63,387 acres in Hand County, 78,366 acres in Faulk County, and 19,660 acres in Spink County.

Upper Wolf Creek is the major tributary in the drainage network of the Lake Louise watershed. It originates in the hills of Ree Heights in eastern Hyde County. There are 217,231 acres in the Lake Louise watershed: 181,605 acres in Hyde County, 34,279 acres in Hand County, and 1,347 acres in Sully County.

Lost Creek, Schaefer Creek, Lower Wolf Creek and North Wolf Creek drainages converge below Lake Louise. This 256,631 acre drainage area does not directly contribute to either Lake Louise or Cottonwood Lake; however, it has been included in this watershed inventory and evaluation as part of a more comprehensive assessment of resources in Hand County.

TABLE 1

Cottonwood Lake and Lake Louise Watershed Assessment Study Area

GIS Acrages Generated from 1:250,000 11-Digit Hydrologic Unit Data

08/17/99

Medicine and Campbell Creeks	**161,413 acres**
(Cottonwood Lake)	
Faulk County	78,366 acres
Hand County	63,387 acres
Spink County	19,660 acres
Upper Wolf Creek	**217,231 acres**
(Lake Louise)	
Hand County	34,279 acres
Hyde County	181,605 acres
Sully County	1,347 acres
North Wolf and Lower Wolf Creeks	**105,700 acres**
Hand County	103,163 acres
Spink County	2,537 acres

Schaefer and Matter Creeks	**88,695 acres**
Hand County	88,695
Lost Creek	**62,236 acres**
Hand County	58,409 acres
Hyde County	3,827 acres

LAND USE

Agriculture is the principal economic activity in the study area. Production of small grains, corn, sunflowers, soybeans, hay, and raising beef cattle are the major enterprises in the watershed.

Approximately 69.6 percent of the study area has some type of permanent vegetative cover. Large acreages of rangeland and interspersed tracts of pasture, hayland, and Conservation Reserve Program (CRP) occur throughout the study area.

Cropland comprises about 28.4 percent of the area. The most common cropping sequence is a rotation of corn, soybeans and small grains. Approximately 70 percent of the cropland acres have some form of residue management (greater than 15 percent ground cover after planting), or are managed using minimum till or no-till conservation tillage systems. Only a small percentage of the cropland is designated as Highly Erodible Land (HEL). Wind erosion is the predominant type of erosion associated with cropland in the study area. Water erosion is a minor resource concern due to the flat slopes and relatively low amount of annual precipitation. Any significant water erosion is associated with the infrequent, localized, thunderstorms that are of high intensity but short duration.

TABLE 2

LAND USE

(Acres)

SUBWATERSHED	TOTAL ACRES	RANGELAND	CROPLAND	HAY/CRP	OTHER
Medicine Creek (Cottonwood Lake)	161,413	80,707	52,703	24,773	3,230
Upper Wolf Creek (Lake Louise)	217,231	173,785	26,947	12,154	4,345
North Wolf Creek	105,700	42,280	52,109	9,196	2,115
Schaefer Creek	88,695	53,217	28,648	5,055	1,775
Lost Creek	62,236	37,342	19,824	3,825	1,245
TOTAL	**635,275**	**387,331**	**180,231**	**55,003**	**12,710**

OTHER includes roads, railroad-right-of-way, farmsteads, and urban areas.

EVALUATION METHODS

Sediment

The Pacific Southwest Interagency Committee (PSIAC) sediment evaluation method was developed as the result of an interagency cooperative effort to assess the average annual sediment yield from watersheds larger than ten square miles. PSIAC evaluations quantify and characterize the watershed sediment yield at a downstream delivery point based on nine physical features within the watershed. It is a method intended for use as an aid to develop and support broad-based resource planning strategies. No other method is currently available to use as a rapid assessment tool for evaluating sediment yield at the watershed level. Sediment surveys and monitoring studies would require more intensive, long term, and costly investigation procedures.

The Natural Resources Conservation Service (NRCS - formerly Soil Conservation Service) Midwest National Technical Center sedimentation geologist approved the use of the PSIAC method of sediment yield evaluation in South Dakota (1993). PSIAC evaluations correlate well with measured results from historic sediment surveys, United States Geological Survey (USGS) gage station data and other sediment data previously collected by various agencies in South Dakota. NRCS has used PSIAC to evaluate sediment yield from agricultural sources for the purpose of broad-based resource planning in river basin studies, watershed plans, and resource assessment reports.

PSIAC has previously been used in South Dakota by NRCS to evaluate sediment loads for the following projects:

Little Minnesota River - Big Stone Lake Watershed Project (1995).

Lower Bad River — River Basin Study (1994).

Upper Bad River — River Basin Study (1998).

Upper Big Sioux — River Basin Study (1999).

Medicine Creek Watershed Assessment Report (1999).

Bear Butte Creek Watershed Assessment Report (1999).

Grand River Watershed Assessment Report (1999).

Phosphorus

The PSIAC sediment evaluations included three sub-watersheds that are not located in the drainage areas of Cottonwood Lake or Lake Louise. These sub-watersheds (North Wolf, Schaefer, and Lost Creeks) were included in the sediment evaluations, however, no water quality sampling was done in these sub-watersheds. Phosphorus concentrations were identified as a resource concern for only the watersheds of Lake Louise and Cottonwood Lake.

Seven water quality-monitoring sites were established along Medicine Creek in the Cottonwood Lake watershed and six sites were located on Upper Wolf Creek in the Lake Louise watershed (Figures 2 and 3). Water quality samples were taken during the 1999 water year and analyzed for various physical and chemical properties, which included total and dissolved phosphorus.

Phosphorus concentrations in soil exist as both organic and inorganic chemical compounds. The amount of phosphorus present varies depending on the soil parent material, texture, and/or management factors such as rates of phosphorus fertilization and cultivation practices. Soil samples taken from the major soil associations in the study area have an average phosphorus concentration of 1.8 pounds of total phosphorus per ton of soil.

Phosphorus transportation, both dissolved and attached, is similar to sediment transport. Phosphorus is either dissolved or in particulate form attached to soil particles. Phosphorus losses are associated with surface runoff and soil erosion.

Very little phosphorus is removed from the system through the process of leaching and none through volatilization. Phosphorus measurements taken at the inlet of each lake were compared to the respective PSIAC values for sediment delivered from the watershed. The ratios of "attached to dissolved" phosphorus were determined from the chemical analyses of the water samples collected for each of the sub-watersheds. These measured concentrations reflect the total phosphorus delivery from the watershed.

PSIAC EVALUATION

Each sub-watershed was evaluated separately to determine the average annual sediment yield delivered to the downstream point of discharge into Lake Louise, Cottonwood Lake, or another watershed. An interdisciplinary planning team (Appendix A) evaluated the nine factors used in the PSIAC method to determine sediment yield. The physical features evaluated are: surface geology, soils, climate, runoff, topography, ground cover, land use and management, upland erosion, and channel development and sediment transport. The sediment yield characteristics of each factor are evaluated and then assigned a numerical value representing the relative significance in the sediment yield rating. The sediment yield rating is a sum of the values for each of the nine factors.

Each of the nine factors has a "paired influence" with the exception of topography. **Surface geology and soils** are directly related; that is, the "parent material" (the geologic formation in which the soil formed) determines the soil characteristics. The other factors that influence each other are **climate and runoff; ground cover and land use;** and **upland erosion and channel development**. Ground cover and land use can have a negative influence on sediment production. The ground cover and/or land use impact on sediment yield is therefore indicated as a negative value when affording better protection than average.

Land treatment measures used for erosion and sediment control will affect the following factors: runoff, land use and management, ground cover, upland erosion, and channel development and sediment transport. The other factors are related to the physical characteristics of the geographical area and do not change with land use or treatment.

Efforts to reduce erosion and sediment production can be measured on a watershed basis by comparing the existing conditions against the expected changes in one or more of the PSIAC factors that relate to the proposed land treatment. An example would be the changes expected when 20 percent of the present rangeland condition is improved by one condition class. This action would reduce runoff, improve ground cover, improve the level of land use and management, and can affect upland erosion and channel development. The total effect is measured as a percent reduction of delivered sediment in the present condition compared to the expected change in sediment delivered after the identified conservation measures are implemented.

PSIAC EVALUATION FACTORS

Surface Geology

The general geology of MLRA (Major Land Resource Area) 53C and MLRA 55C is a result of the different periods of glaciation that occurred during the Pleistocene. The surface geology of the study area is glacial till with isolated areas of sand and gravel deposits.

Soils

The majority of the soils in the study area are nearly level to gently sloping or undulating loamy soils formed in glacial till or melt-water deposits. Rolling to hilly soils formed in mixed materials are present in significant amounts in the Medicine Creek sub-watershed, but occur only as a minor component in the rest of the sub-watersheds.

Climate

The climate of central South Dakota is sub-humid and continental, characterized by large seasonal fluctuations in temperature, moderate to high relative humidity, and frequent high winds. Recurring periods of drought or near drought conditions are common. Less frequent periods of short duration can yield higher than normal amounts of precipitation. The average annual precipitation is 18.6 inches with 75 percent occurring during the period April to September, which is the growing season for most of the crops raised in this area. The growing season ranges from 115 days to 130 days. The average last killing frost occurs in mid-May and the first killing frost generally occurs in mid-September. Seasonal fluctuations in temperatures range from well below zero in winter to 100 + degree-days in July or August. Many freeze-thaw events occur in the fall and early spring.

Runoff

Precipitation and runoff rates in South Dakota differ annually and with season and location. Storms are generally of moderate intensity and short duration, and localized thunderstorms of high intensity and short duration are common. Approximately 70 percent of runoff occurs as a result of snowmelt and rainfall in the spring and early summer. The study area is located in an area that the U.S. Geological Survey has designated as Hydrologic sub-region B which has a moderate rating for runoff. There are scattered wetlands throughout the study area. Upper Wolf Creek is the only sub-watershed that has significant wetlands affecting runoff.

Topography

The study area lies in the James River Lowland section of the Central Lowland Physiographic Division. The generally flat slopes of the prairie characterize the topography of the study area with little local relief in the low rolling hills and stream channels. Elevations range from 2,000 feet mean sea level (msl) in the Ree Hills of the Upper Wolf Creek sub-watershed to about 1,350 feet msl in the Medicine Creek sub-watershed.

Ground Cover

Ground cover is described as anything on or above the surface of the ground, which alters the effect of precipitation on the soil surface and soil profile. Included in this factor are vegetation, litter, and rock fragments. A good ground cover acts to dissipate the energy of rainfall before it strikes the soil surface, deliver water to the soil at a relatively uniform rate, impede the overland flow of water, and promote infiltration by the action of roots within the soil. Conversely, the absence of ground cover, whether through natural growth habits or the effects of overgrazing, tillage, or fire, leaves the land surface open to the worst effects of storms.

Differences in vegetative type have a variable effect on erosion and sediment yield, even though percentages of total ground cover may be the same. For instance, the sod forming short grasses can have vastly different rates of runoff from the same range sites when compared to the intermediate/tall grasses. The sod forming grasses, which have a shallow, dense root system, have a lower rate of infiltration and therefore higher rates of runoff. The intermediate/tall grasses have a deeper root system that promotes a greater rate of infiltration and less runoff. Even though the ground cover is effective at both sites, there is the potential to impact sediment yield off-site due to the differences in amount of runoff and infiltration.

Land Use and Management

The use of land has a widely variable impact on sediment yield, depending largely on the susceptibility of the soil and rock to erosion, the amount of stress exerted by climatic factors and the type and intensity of use. In almost all instances, the land use either removes or reduces the amount of natural vegetative cover, which in turn affects the varied relationships within the environment. In certain instances, the loss or deterioration of vegetative cover may have little noticeable on-site impact but may increase off-site erosion, an effect of a higher volume and an acceleration of runoff.

Upland Erosion

Upland erosion occurs on sloping watershed lands beyond the confines of valleys. Sheet erosion, which involves the removal of a thin layer of soil over an extensive area, is usually not visible to the eye. This erosion type is evidenced by the formation of rills. Experience indicates that soil loss from sheet and rill erosion can be seen if it amounts to about five tons or more per acre.

A gully is defined as a small channel with steep sides caused by erosion from concentrated but intermittent flow of water usually during and immediately following heavy rains or after ice/snow melt. Significant gully erosion contributing to sediment loads is evidenced by the presence of numerous raw cuts along the hill slopes or areas of concentrated flow and sediment deposition in gently sloping or nearly level cropland areas. Deep soils on moderately steep to steep slopes usually provide an environment for gully development.

Downslope soil movement due to slumping or mass wasting can be an important factor in sediment yield on steep slopes that are underlain by unstable geologic formations.

Wind erosion from upland slopes and the deposition of the eroded material in stream channels can be a significant factor. The material deposited in channels is readily moved by subsequent runoff. Wind erosion is the major source of sediment from cropland in the study area.

Channel Erosion and Sediment Transport

Channel erosion and sediment transport are a function of the drainage network that has developed within the watershed. A healthy, well-developed drainage network will efficiently transport "normal" sediment loads. Networks that are healthy will transport runoff and sediment loads with no adverse effects from incised channels or floodplain degradation. Drainage networks that are unstable have channels that are down cutting and producing sediment loads that cannot be handled by the channel system. Poorly developed drainage networks characterize areas that serve as natural sediment retention basins.

PSIAC RESULTS

The inventoried sub-watersheds had a sediment production range of 0.48 tons per acre for the Upper Wolf Creek sub-watershed (Lake Louise) to 0.87 tons per acre in the Medicine Creek (Cottonwood Lake) sub-watershed. The three other sub-watersheds have approximately a 0.6 tons per acre sediment delivery rate. The lower sediment delivery rate of the Upper Wolf Creek sub-watershed can be attributed to the large number of ponds, wetlands, and water spreading-dike systems within the drainage area that act as sediment traps. Lake Mitchell is also located in the watershed and influences the amount of runoff from the upper third of the Upper Wolf Creek drainage area.

TABLE 3

PSIAC SEDIMENT DELIVERY RATE

(Tons/Acres)

SUBWATERSHED	TOTAL ACRES	TONS/ACRE	TONS
Medicine Creek (Cottonwood Lake)	161,413	0.87	140,430
Upper Wolf Creek (Lake Louise)	217,231	0.48	104,270
North Wolf Creek	105,700	0.63	66,590
Schaefer Creek	88,695	0.6	53,220
Lost Creek	62,236	0.6	37,340
TOTAL	**635,275**		**401,850**

The PSIAC sediment delivery rates for the study area compare well with a 1969 SCS (NRCS) sediment survey completed on Richmond Lake in Brown County, South Dakota. Richmond Lake is located approximately 65 miles north of Cottonwood Lake and has a drainage area of 73.5 square miles (47,040 acres). The Richmond Lake watershed and Cottonwood Lake watershed have similar geology, soils, climate, topography, hydrology, and land use. During the 32-year interval from 1937 to 1969 measured sediment accumulations in the lake amounted to an average annual 1.1 tons per acre of sediment delivered from the Richmond Lake watershed. This correlates closely to the PSIAC sediment delivery rate of 0.87 tons per acre in the Cottonwood Lake watershed.

SEDIMENT EVALUATIONS

PSIAC evaluations of the sub-watersheds estimate the sediment yield from all sources delivered to the mouth of the drainage area. Additional analysis is needed in order to apportion the sediment load among the different land use types and to develop land treatment strategies. Each sub-watershed was inventoried for the land use (Table 2, **Page 5)** and sediment contributions were determined for each type of land use (Table 4).

TABLE 4

PRESENT CONDITION SEDIMENT

SUBWATERSHED	ACRES	RANGELAND (TONS)	CROPLAND (TONS)	HAY/CRP (TONS)
Medicine Creek (Cottonwood Lake)	161,413	62,780	70,070	7,585
Upper Wolf Creek (Lake Louise)	217,231	79,920	20,110	4,235
North Wolf Creek	105,700	20,160	44,265	2,165
Schaefer Creek	88,695	25,630	26,280	1,310
Lost Creek	62,236	18,190	18,175	975
TOTAL	635,275	206,680	178,900	16,270

TOTAL SEDIMENT 401,850 TONS

In each sub-watershed, the acres of rangeland were divided into four condition classes; excellent, good, fair, and poor in order to assess reduction in sediment yield with improved range condition (Table 5). Rangeland in excellent condition has 76 to 100 percent of the original native vegetation consisting of the most desirable perennial forage plants. Native legumes and other desirable forbs are usually present. Good condition rangeland has a 51 to 75 percent mixture of original native vegetation. Some legumes and forbs may be present. Fair condition rangeland is characterized by a 26 to 50 percent mixture of original native vegetation, some legumes may be present, but most of the forbs that occur are the less desirable increasers or invaders. Overall vegetation appearance is shorter and the amount of bare ground generally is increasing. Poor condition rangeland vegetation has less than 25 percent of the highly palatable, desirable perennial plants. Invaders and increasers comprise the majority of the vegetation.

TABLE 5

PRESENT CONDITION RANGELAND
(ACRES)

		RANGE CONDITION CLASS (ACRES)			
SUBWATERSHED	RANGELAND ACRES	POOR (Acres)	FAIR (Acres)	GOOD (Acres)	EXCELLENT (Acres)
Medicine Creek (Cottonwood Lake)	80,707	40,353	32,282	4,036	4,036
Upper Wolf Creek (Lake Louise)	173,785	34,757	95,582	26,068	17,387
North Wolf Creek	42,280	12,684	23,254	4,228	2,114
Schaefer Creek	53,217	10,111	30,866	7,983	4,257
Lost Creek	37,342	7,468	22,405	3,734	3,734
TOTAL	**387,331**	**105,373**	**204,389**	**46,049**	**31,528**

The sediment production from the different range condition classes was determined for each of the sub-watersheds based on standard NRCS procedures from the Engineering Field Manual for South Dakota, Chapter 11, Amendment 15 (Table 6).

TABLE 6

PRESENT CONDITION RANGELAND SEDIMENT (TONS)					
	RANGELAND	RANGE CONDITION CLASS (TONS)			
SUBWATERSHED	ACRES	POOR (Tons)	FAIR (Tons)	GOOD (Tons)	EXCELLENT (Tons)
Medicine Creek (Cottonwood Lake)	80,707	37,360	21,910	2,010	1,210
Upper Wolf Creek (Lake Louise)	173,785	20,220	45,480	9,670	4,345
North Wolf Creek	42,280	7,780	10,465	1,390	635
Schaefer Creek	53,217	6,690	14,990	2,820	1,275
Lost Creek	37,342	4,960	10,915	1,325	1,120
TOTAL	**387,331**	**77,010**	**103,760**	**17,215**	**8,705**
TOTAL SEDIMENT FROM RANGELAND			**206,680 TONS**		

The cropland was divided into four categories based on residue after planting: less than 15 percent; greater than 15 percent but less than 30 percent; greater than 30 percent but less than 70 percent; and greater than 70 percent. The county averages for the different residue management systems were used to prorate the acres for each category in the sub-watersheds (Table 7).

TABLE 7

PRESENT CONDITION					
	CROPLAND	PERCENT RESIDUE (ACRES)			
SUBWATERSHED	ACRES	<15 % (Acres)	>15 % <30 % (Acres)	>30 % <70 % (Acres)	>70 % (Acres)
Medicine Creek (Cottonwood Lake)	52,703	17,333	15,621	11,646	8,103
Upper Wolf Creek (Lake Louise)	26,947	6,591	7,073	8,476	4,807
North Wolf Creek	52,109	14,643	15,200	14,267	7,999
Schaefer Creek	28,648	8,050	8,357	7,844	4,397
Lost Creek	19,824	5,527	5,747	5,477	3,073
TOTAL	**180,231**	**52,144**	**51,998**	**47,710**	**28,379**

Using the Revised Universal Soil Loss Equation (RUSLE), erosion rates were calculated for each of the residue management levels. Sediment yields were calculated using standard NRCS procedures from the Engineering Field Manual for South Dakota, Chapter 11, Amendment 15 (Table 8).

TABLE 8

PRESENT CONDITION CROPLAND SEDIMENT (TONS)

SUBWATERSHED	CROPLAND ACRES	PERCENT RESIDUE < 15% (Tons)	>15% < 30% (Tons)	>30% < 70% (Tons)	> 70% (Tons)
Medicine Creek (Cottonwood Lake)	52,703	26,000	18,745	8,735	4,005
Upper Wolf Creek (Lake Louise)	26,947	6,590	5,660	5,085	1,780
North Wolf Creek	52,109	21,965	18,240	10,700	2,610
Schaefer Creek	28,648	12,075	10,030	5,885	1,550
Lost Creek	19,824	8,290	6,895	4,110	1,090
TOTAL	**180,231**	**75,070**	**59,030**	**33,770**	**11,035**

TOTAL SEDIMENT FROM CROPLAND 178,905 TONS

STRATEGIES FOR SEDIMENT REDUCTION

There are numerous combinations of conservation practices that can be used to reduce sediment. The measures that are used for erosion and sediment control in South Dakota may be classified by purpose into several groups: 1.) To intercept and/or conserve moisture; 2.) To increase infiltration capacity; 3.) To reduce or eliminate stress on existing cover; 4.) To preserve existing cover regarded as adequate or in the process of becoming adequate with time; 5.) To increase the protection of the soil by a change in the type as well as density of vegetation.

As part of the assessment for the Lake Louise – Cottonwood Lake study area, four different levels of resource management practice application were assessed. The first level considered was the continuation of present conditions with no additional special projects or funding for sediment and erosion control conservation practices (Tables 3,4,5,6,and 7). Three other levels of consideration (low, moderate, high) were based on an increase in the total number of acres with improved rangeland grazing management and/or cropland residue management for erosion and sediment control. The low, moderate, and high levels of participation were selected to represent a reasonable expectation of change if there were an attempt to increase the level of resource management application. A comparison between the different levels of landowner participation provides a guide to the expected decrease in sediment versus the number of acres that would need to be treated to achieve any goals set for sediment reduction.

PRESENT CONDITION

If there are no significant changes in the present land use and on-going conservation programs remain funded at the present level there will be no significant changes in the amount of sediment produced in the watershed. Range condition will probably remain as is, with no long term trend either up or down. Presently 30 percent of the rangeland is under some type of range management. Crop residue management trends indicate that there is an annual increase of approximately two-percent in the number of acres that change to a higher level of residue use. Approximately 70 percent of the cropland acres have some level of residue management at this time. Since the majority of the land use is rangeland, the increase in residue management will not significantly affect reductions in total sediment.

LOW PARTICIPATION RATE

The low level of participation is an estimate of sediment reduction that can be expected if 20 percent of the rangeland in the watershed is managed to improve these acres one condition class. Typical range management practices would include grazing distribution, proper grazing use, and prescribed grazing systems. The sediment reduction in the Medicine Creek sub-watershed (Cottonwood Lake) would be 5.2 percent from rangeland (Table 9) or 2.3 percent of the total sediment load. The Upper Wolf Creek sub-watershed (Lake Louise) would have a sediment reduction of 4.7 percent from the rangeland (Table 9), a reduction in the total sediment of 3.6 percent.

Sediment reduction from the cropland acres was based on 10 percent of the cropland acres increasing residue management by one level. Typical conservation practices that could be used are changes from conventional tillage to minimum or no-till, changing cropping sequence, or establishing a permanent vegetative cover. The Medicine Creek sub-watershed (Cottonwood Lake) would have 4.0 percent reduction in sediment from the cropland (Table 10) and a 2.0 percent total reduction of sediment. In the Upper Wolf Creek sub-watershed (Lake Louise) there would be a 2.6 percent reduction of sediment from cropland (Table 10) with an overall reduction of 0.5 percent.

MODERATE PARTICIPATION RATE

The moderate participation for rangeland was assumed to be increased management on 30 percent of the acres resulting in an improvement in the range condition one condition class. Medicine Creek (Cottonwood Lake) would have a 7.8 percent decrease from rangeland (Table 9) and a 3.5 percent total reduction. The Upper Wolf Creek sub-watershed (Lake Louise) would have a 6.2 percent reduction (Table 9) or an overall sediment reduction of 4.8 percent.

A 15 percent increase of one residue management level was assumed for the cropland acres. The Medicine Creek sub-watershed (Cottonwood Lake) would have a 4.3 percent decrease from cropland (Table 10) and an overall reduction of 2.1 percent. Upper Wolf Creek (Lake Louise) would have a 3.8 percent reduction of sediment from cropland (Table 10) or a 0.7 percent total reduction.

HIGH PARTICIPATION RATE

Forty percent was used for the high participation rate for rangeland. Sediment reductions were based on 40 percent of the rangeland acres with improved management to achieve an improvement of one condition class. There would be a 10.5 percent reduction from rangeland sediment (Table 9) or a total reduction of 4.7 percent in the Medicine Creek sub-watershed (Cottonwood Lake). The Upper Wolf Creek sub-watershed (Lake Louise) would have an 8.3 percent reduction in rangeland sediment (Table 9) or a total reduction of 6.3 percent. A 20 percent participation rate was used for the cropland. The Medicine Creek sub-watershed (Cottonwood Lake) would have a 5.7 percent decrease in sediment from cropland (Table 10) and an overall reduction of 2.9 percent. The Upper Wolf Creek sub-watershed (Lake Louise) would have a 5.1 percent reduction of cropland sediment (Table 10) and a total reduction of 1.0 percent.

TABLE 9

RANGELAND SEDIMENT
(TONS)

SUBWATERSHED	RANGELAND ACRES	PRESENT SEDIMENT (Tons)	SEDIMENT REDUCTIONS PARTICIPATION RATES LOW (Tons)	% CHANGE	MODERATE (Tons)	% CHANGE	HIGH (Tons)	% CHANGE
Medicine Creek (Cottonwood Lake)	80,707	62,785	59,520	5.2	57,890	7.8	56,195	10.5
Upper Wolf Creek (Lake Louise)	173,785	79,925	76,170	4.7	74,970	6.2	73,290	8.3
North Wolf Creek	42,280	20,160	19,110	5.2	18,590	7.8	18,045	10.5

Schaefer Creek	53,217	25,630	24,325	5.1	23,655	7.7	23,015	10.2
Lost Creek	37,342	18,190	17,260	5.1	16,790	7.7	16,790	11.3
TOTAL	**387,331**	**206,690**	**196,385**		**191,895**		**186,680**	
PERCENT REDUDCTION				**5.0**		**7.2**		**9.7**

TABLE 10

CROPLAND SEDIMENT
(TONS)

SUBWATERSHED	CROPLAND ACRES	PRESENT SEDIMENT (Tons)	SEDIMENT REDUCTIONS / PARTICIPATION RATE: LOW (Tons)	% CHANGE	MODERATE (Tons)	% CHANGE	HIGH (Tons)	% CHANGE
Medicine Creek (Cottonwood Lake)	52,700	70,075	67,200	4.1	67,060	4.3	66,080	5.7
Upper Wolf Creek (Lake Louise)	26,947	20,110	19,590	2.6	19,345	3.8	19,085	5.1
North Wolf Creek	52,109	44,265	42,940	3.0	42,275	4.5	41,610	6.0
Schaefer Creek	28,648	26,280	25,490	3.0	25,100	4.5	24,705	6.0
Lost Creek	19,824	18,175	17,630	3.0	17,360	4.5	17,085	6.0
TOTAL	**180,231**	**178,905**	**172,850**		**171,140**		**168,565**	
PERCENT REDUCTION				**3.4**		**4.4**		**5.8**

The estimated reductions in sediment based on the Low, Moderate, or High participation rates are very conservative. This would be the minimum amount of reduction that could be expected. The changes for the different participation rates were prorated by percentage of existing land use and condition for each sub-watershed. This means that rangeland or cropland acres already managed at the higher levels were included when sediment reductions were calculated. There was no allowance for improving conditions by more than one class, (i.e. poor range condition was assumed to only improve to fair condition and not good or excellent). Neither was there any attempt to consider changes related to land use. The results reflect a generalized “across the board” type of change.

Additional conservation practices used in conjunction with rangeland or cropland management would greatly enhance the overall reduction of sediment from the study area. An example would be the use of buffer or filter strips along with improved residue management, or fencing riparian areas for dormant season grazing. It was beyond the scope of this assessment to evaluate individual, site-specific conservation practices.

A more detailed evaluation would need to be made to assess additional reductions based on other assumptions. This would be appropriate if there is a specific project or study proposed for a sub-watershed. Based on recent NRCS River Basin studies (Lower Bad River, 1994, Upper Bad River, 1998) significant sediment reductions can be expected from implementing a combination of conservation practices in addition to management systems. The Little Minnesota River-Big Stone Lake Watershed Project (NRCS, 1995) also projected significant reductions in phosphorus and sediment based on the implementation of conservation practices and land management treatment at various levels. The recommended plans had a favorable cost-benefit ratio and projected reductions up to 36 percent (Little Minnesota-Big Stone Lake Watershed Project).

PHOSPHORUS EVALUATION

The results from the water quality monitoring sites indicate that the ratio of dissolved phosphorus to total phosphorus is quite high (Table 11). The sediment attached portion of the measured phosphorus levels is not the most significant source of phosphorus delivered to Cottonwood Lake and Lake Louise. Additional evaluations of the watersheds should be completed to identify the possible sources of phosphorus that are not predominantly related to sediment.

TABLE 11

WATER YEAR 1999

PRESENT CONDITION PHOSPHORUS LOADINGS (POUNDS)

SUBWATERSHED	SITE	WATER VOLUME (GALLONS)	TOTAL PHOSPHATE (POUNDS)	TOTAL DISSOLVED PHOSPHATE (POUNDS)	RATIO DISSOLVED/ TOTAL (%)
Medicine Creek (Cottonwood Lake)	MC 1	469,030,233	4,061	3,722	92
	MC 2	594,237,738	5,688	5,294	93
	MC 3	131,099,041	371	345	93
	MC 4	719,165,762	4,682	3,435	73

	MC 5	862,689,875	7,011	6,004	86
	MC 6	2,175,568,064	11,467	7,391	64
Outlet	MC 7	2,816,783,468	5,344	2,820	53

TOTAL PHOSPHORUS DELIVERED TO COTTONWOOD LAKE 11,467 POUNDS

Upper Wolf Creek	WC 1	489,952	2.118	1.582	75
(Lake Louise)	WC 2	2,932,468	0	0	
	WC 3	1,671,824	4.618	4.004	87
	WC 4	2,374,526	0	0	
	WC 5	33,400,924	128.788	112.341	87
Outlet	WC 6	43,098,794	173.196	142.262	82

TOTAL PHOSPHORUS DELIVERED TO LAKE LOUISE 128.8 POUNDS

WATER YEAR SPRING 2000

PRESENT CONDITION PHOSPHORUS LOADINGS (POUNDS)

SUBWATERSHED	SITE	WATER VOLUME (GALLONS)	TOTAL PHOSPHATE (POUNDS)	TOTAL DISSOLVED PHOSPHATE (POUNDS)	RATIO DISSOLVED/ TOTAL (%)
Medicine Creek (Cottonwood Lake)	MC 1	469,030,233	1,637	1,470	90
	MC 2	594,237,738	2,121	1,927	91
	MC 3	131,099,041	171	159	93
	MC 4	719,165,762	1,544	619	40
	MC 5	862,689,875	1,459	1,142	78
	MC 6	2,175,568,064	5,894	3,468	59
Outlet	MC 7	2,816,783,468	2,901	1,385	47

TOTAL PHOSPHORUS DELIVERED TO COTTONWOOD LAKE 5,894 POUNDS

CONCLUSIONS

The PSIAC sediment evaluations for the study area can provide a baseline for developing conservation practice implementation strategies for sediment reduction. In order to achieve a more substantial reduction in sediment delivered to Lake Louise, Cottonwood Lake, or other downstream watersheds, it will take more than cropland residue or grazing management. Other conservation practices for sediment and erosion control in combination with proper management are needed to effectively change sediment yield. Total Resource Management Systems or

Progressive Conservation Planning in conjunction with the implementation of Best Management Practices would help to achieve the desired sediment reduction.

Water quality data indicate that the major sources of phosphorus in the watersheds are not sediment related. Total and Dissolved phosphorus values suggest that phosphorus loads are related to runoff from areas that have higher phosphorus concentrations than what is normally found in the soils.

APPENDIX A

Study Contributors and Participants

Name	Present Title (Years)	Education	Previous Experience (Years)	
Robert Bartelson	Soil Conservationist	BS	Soil Cons Tech	
Karen Brannen	Soil Conservationist	BS Agronomy (Soils)	Soil Cons	4

	2		Res Cons 8 Soil Scientist 11
Joni Glanzer	GIS Specialist		
Grady Heitman	District Conservationist	BS	Soil Cons
Mike Knigge	Cartographic Technician		
Sean Kruger	Project Coordinator	BS	
Marvin Nelson	District Conservationist	BS	Soil Cons Soil Cons Tech
Duane Nielsen	Technician		
Robert Smith	Environmental Scientist	BS	
Cindy Steele	Environmental Engineer 8	BS Biology MS Env. Eng PhD Grad Study	Soil Cons 4
Kelly Stout	District Conservationist	BS	Soil Cons

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Appendix C. AGNPS Data

Lot #	AGNPS Ranking Number	Sub Watershed Location	Percent of AFO Load	Predicted Annual AFO Load to Cottonwood Lake	Percent of Annual AFO Load To Cottonwood Lake
33	92	1	42.7%	981.2	16.6%
41	55	1	4.5%	103.4	1.8%
50	53	3	3.7%	85.0	1.4%
17	53	4	3.2%	73.5	1.2%
17	48	4	3.5%	80.4	1.4%
49	48	2	1.8%	41.4	0.7%
13	48	5	3.1%	71.2	1.2%
2	47	6	3.2%	73.5	1.2%
39	47	1	2.3%	52.9	0.9%
1	46	7	2.6%	59.7	1.0%
12	46	6	2.3%	52.9	0.9%
22	46	5	2.3%	52.9	0.9%
48	42	2	1.1%	25.3	0.4%
58	41	1	1.7%	39.1	0.7%
11	41	4	1.7%	39.1	0.7%
48	40	2	1.9%	43.7	0.7%
42	38	2	1.6%	36.8	0.6%
57	35	4	1.1%	25.3	0.4%
40	34	1	1.1%	25.3	0.4%
29	34	1	0.9%	20.7	0.4%
37	33	1	0.9%	20.7	0.4%
28	32	4	0.9%	20.7	0.4%
43	32	2	0.9%	20.7	0.4%
53	27	3	0.7%	16.1	0.3%
54	25	5	0.6%	13.8	0.2%
25	23	4	0.2%	4.6	0.1%
55	22	5	0.5%	11.5	0.2%
21	19	5	0.2%	4.6	0.1%
18	16	4	0.2%	4.6	0.1%
27	12	4	0.2%	4.6	0.1%
14	0	6	0.0%	0.0	0.0%
52	0	3	0.0%	0.0	0.0%
10	0	6	0.0%	0.0	0.0%
14	0	6	0.0%	0.0	0.0%
8	0	6	0.0%	0.0	0.0%
47	0	5	0.0%	0.0	0.0%
7	0	6	0.0%	0.0	0.0%
6	0	6	0.0%	0.0	0.0%
5	0	6	0.0%	0.0	0.0%
4	0	6	0.0%	0.0	0.0%
3	0	7	0.0%	0.0	0.0%
56	0	5	0.1%	2.3	0.0%
9	0	6	0.0%	0.0	0.0%
24	0	4	0.0%	0.0	0.0%
35	0	1	0.6%	13.8	0.2%
31	0	1	0.0%	0.0	0.0%
30	0	1	0.0%	0.0	0.0%

36	0	1	0.0%	0.0	0.0%
16	0	5	0.0%	0.0	0.0%
26	0	4	0.0%	0.0	0.0%
15	0	6	0.0%	0.0	0.0%
23	0	4	0.0%	0.0	0.0%
45	0	4	0.0%	0.0	0.0%
20	0	4	0.0%	0.0	0.0%
19	0	4	0.0%	0.0	0.0%
34	0	1	0.0%	0.0	0.0%
51	0	2	0.0%	0.0	0.0%
44	0	2	0.0%	0.0	0.0%
32	0	1	0.0%	0.0	0.0%
46	0	2	0.0%	0.0	0.0%
38	Not Rated	1	0.0%	0.0	0.0%

Appendix D. Daily Discharges For Medicine Creek Tributary Sites

daily flow data (CFS)

date	mc-7	mc-6	mc-5	mc-4	mc-3	mc-2	mc-1
05/12/99	283.00	356.93	152.44	125.00	19.02	87.19	117.21
05/13/99	343.00	321.76	134.14	113.85	15.88	81.77	94.96
05/14/99	404.13	286.59	117.00	102.77	12.73	76.61	75.84
05/15/99	358.66	251.42	101.02	92.25	12.03	71.72	59.59
05/16/99	313.20	216.26	86.20	82.29	11.33	67.08	45.98
05/17/99	267.73	181.09	72.55	72.89	10.62	62.69	34.77
05/18/99	222.26	145.93	60.06	64.05	9.92	58.53	25.72
05/19/99	195.69	128.38	48.73	51.68	7.95	44.11	18.58
05/20/99	169.11	110.83	38.57	40.89	5.98	32.80	13.12
05/21/99	154.43	97.68	34.57	31.96	5.20	27.55	9.93
05/22/99	139.74	86.54	30.78	24.07	4.42	23.08	7.47
05/23/99	125.06	75.40	27.21	18.04	3.64	19.30	5.62
05/24/99	110.38	64.26	23.85	13.58	2.87	16.14	4.29
05/25/99	95.70	53.12	20.70	10.71	2.09	13.52	3.36
05/26/99	81.01	41.97	17.77	9.42	1.31	11.38	2.74
05/27/99	66.33	30.83	15.05	9.72	0.53	9.65	2.30
05/28/99	63.35	30.57	14.55	10.06	0.82	9.01	2.39
05/29/99	60.38	30.30	14.05	10.39	1.11	8.43	2.48
05/30/99	57.40	30.04	13.56	10.73	1.40	7.91	2.83
05/31/99	54.42	29.78	13.08	11.06	1.69	7.44	3.31
06/01/99	51.44	29.52	12.61	11.40	1.98	7.02	3.94
06/02/99	48.47	29.26	12.15	11.73	2.26	6.65	4.78
06/03/99	45.49	29.00	11.69	12.07	2.55	6.32	5.87
06/04/99	42.51	28.74	11.25	12.40	2.84	6.02	7.26
06/05/99	39.53	28.49	10.81	12.74	3.13	5.76	8.97
06/06/99	36.56	28.23	10.38	13.07	3.42	5.53	11.07
06/07/99	33.58	27.98	9.95	13.41	3.71	5.33	13.59
06/08/99	30.60	27.73	9.54	13.74	4.00	5.15	16.58
06/09/99	28.46	19.94	8.73	9.77	6.06	4.79	12.60
06/10/99	26.33	19.89	7.96	10.27	8.12	4.64	9.47
06/11/99	24.19	20.46	7.22	13.29	7.97	4.49	7.08
06/12/99	22.05	19.69	6.51	12.38	6.44	4.34	5.31
06/13/99	19.92	18.57	5.83	10.68	6.25	4.19	4.05
06/14/99	17.78	17.37	5.19	9.05	5.21	4.04	3.18
06/15/99	17.34	17.25	5.19	7.39	1.56	4.02	3.03
06/16/99	16.89	16.12	5.19	5.80	0.53	4.01	2.89
06/17/99	16.45	15.75	5.19	4.38	0.12	3.99	2.76
06/18/99	16.00	15.98	5.19	2.76	0.00	3.98	2.65
06/19/99	15.56	15.18	5.19	2.33	0.00	3.96	2.54
06/20/99	15.11	14.64	5.19	1.85	0.00	3.94	2.44
06/21/99	14.67	11.36	5.19	2.11	0.00	3.93	2.35
06/22/99	14.22	5.77	5.19	1.36	0.00	3.91	2.26
06/23/99	13.45	4.88	5.19	0.99	0.00	3.90	2.18
06/24/99	12.67	4.34	5.19	0.72	0.00	2.87	2.10
06/25/99	11.89	6.16	4.46	0.74	0.00	2.50	2.02

daily flow data (CFS)

date	mc-7	mc-6	mc-5	mc-4	mc-3	mc-2	mc-1
06/26/99	11.12	5.44	4.82	0.22	0.00	1.88	1.94
06/27/99	10.34	5.51	5.19	0.29	0.00	2.09	1.86
06/28/99	9.57	6.19	5.57	0.41	0.00	3.15	1.77
06/29/99	8.80	3.87	7.22	0.85	0.00	3.92	1.69
06/30/99	9.41	3.89	7.22	0.78	0.00	3.89	1.85
07/01/99	8.21	3.77	8.57	0.93	0.00	3.85	1.69
07/02/99	8.21	3.88	9.54	1.44	0.01	3.78	1.85
07/03/99	8.80	3.88	9.54	1.87	4.40	3.62	2.15
07/04/99	8.80	3.85	10.04	1.84	2.62	3.25	2.30
07/05/99	8.21	3.67	9.54	1.44	0.02	2.87	2.30
07/06/99	7.63	3.46	9.05	0.93	0.00	2.43	2.15
07/07/99	7.63	3.08	7.22	0.53	0.00	1.88	1.50
07/08/99	7.63	2.81	5.96	0.29	0.00	1.67	1.43
07/09/99	4.00	2.35	4.46	0.26	0.00	1.23	1.18
07/10/99	4.00	2.08	3.13	0.01	0.00	1.09	0.94
07/11/99	3.55	1.83	1.74	0.01	0.00	0.82	0.63
07/12/99	2.70	1.79	0.46	0.01	0.00	0.24	0.41
07/13/99	2.70	1.57	0.41	0.00	0.00	0.29	0.63
07/14/99	2.30	1.37	0.85	0.00	0.00	0.20	0.00
07/15/99	3.55	1.47	0.92	0.00	0.00	0.20	0.00
07/16/99	2.30	1.39	0.67	0.00	0.00	0.20	0.00
07/17/99	2.30	1.44	0.39	0.00	0.00	0.45	0.00
07/18/99	1.93	1.71	0.00	0.00	0.00	0.75	0.00
07/19/99	1.93	1.62	0.00	0.00	0.00	0.95	0.00
07/20/99	1.93	1.56	0.00	0.00	0.00	1.81	0.00
07/21/99	1.93	1.65	0.00	0.00	0.00	1.67	0.00
07/22/99	2.30	1.74	0.00	0.00	0.00	1.23	0.00
07/23/99	1.58	1.84	0.00	0.00	0.00	0.95	0.00
07/24/99	1.93	1.93	0.00	0.00	0.00	0.00	0.00
07/25/99	1.58	2.03	0.00	0.00	0.00	0.05	0.00
07/26/99	0.68	2.13	0.00	0.00	0.00	0.00	0.00
07/27/99	0.95	2.23	0.00	0.00	0.00	0.00	0.00
07/28/99	0.68	2.34	0.00	0.00	0.00	0.00	0.00
07/29/99	0.44	2.44	0.00	0.00	0.00	0.00	0.00
07/30/99	0.24	2.55	0.00	0.00	0.00	0.00	0.00
07/31/99	0.00	2.66	0.00	0.00	0.00	0.00	0.00
08/01/99	0.00	2.77	0.00	0.00	0.00	0.00	0.00
08/02/99	0.00	2.89	0.00	0.00	0.00	0.00	0.00
08/03/99	0.00	3.00	0.00	0.00	0.00	0.00	0.00
08/04/99	0.00	3.12	0.00	0.00	0.00	0.00	0.00
08/05/99	0.00	3.24	0.00	0.00	0.00	0.00	0.00
08/06/99	0.00	3.36	0.00	0.00	0.00	0.00	0.00
08/07/99	0.00	3.48	0.00	0.00	0.00	0.00	0.00
08/08/99	0.00	3.61	0.00	0.00	0.00	0.00	0.00
08/09/99	0.00	3.74	0.00	0.00	0.00	0.00	0.00
08/10/99	0.00	3.86	0.00	0.00	0.00	0.00	0.00
08/11/99	0.00	4.00	0.00	0.00	0.00	0.00	0.00

daily flow data (CFS)

date	mc-7	mc-6	mc-5	mc-4	mc-3	mc-2	mc-1
08/12/99	0.00	4.26	0.00	0.00	0.00	0.00	0.00
08/13/99	0.00	4.00	0.00	0.00	0.00	0.00	0.00
08/14/99	0.00	3.78	0.00	0.00	0.00	0.00	0.00
08/15/99	0.00	3.61	0.00	0.00	0.00	0.00	0.00
08/16/99	0.00	3.38	0.00	0.00	0.00	0.00	0.00
08/17/99	0.00	2.76	0.00	0.00	0.00	0.00	0.00
08/18/99	0.00	2.27	0.00	0.00	0.00	0.00	0.00
08/19/99	0.00	2.56	0.00	0.00	0.00	0.00	0.00
08/20/99	0.00	2.57	0.00	0.00	0.00	0.00	0.00
08/21/99	0.00	2.69	0.00	0.00	0.00	0.00	0.00
08/22/99	0.00	2.13	0.00	0.00	0.00	0.00	0.00
08/23/99	0.00	0.14	0.00	0.00	0.00	0.00	0.00
08/24/99	0.00	0.15	0.00	0.00	0.00	0.00	0.00
08/25/99	0.00	0.10	0.00	0.00	0.00	0.00	0.00
08/26/99	0.00	0.06	0.00	0.00	0.00	0.00	0.00
08/27/99	0.00	0.04	0.00	0.00	0.00	0.00	0.00
08/28/99	0.00	0.21	0.00	0.00	0.00	0.00	0.00
08/29/99	0.00	1.22	0.00	0.00	0.00	0.04	0.00
08/30/99	0.00	1.70	0.00	0.00	0.00	0.20	0.00
08/31/99	0.00	1.21	0.00	0.00	0.00	1.45	0.00
09/01/99	0.00	1.28	0.00	0.00	0.00	0.63	0.00
09/02/99	0.00	2.32	0.00	0.00	0.00	0.20	0.00
09/03/99	0.00	3.97	0.00	0.00	0.00	0.89	0.00
09/04/99	0.00	3.32	0.00	0.00	0.00	2.50	0.41
09/05/99	0.00	2.20	0.00	0.00	0.00	2.81	0.41
09/06/99	0.00	1.53	0.00	0.00	0.00	1.59	0.33
09/07/99	0.00	1.12	0.00	0.06	0.00	0.75	0.25
09/08/99	0.00	0.86	0.00	0.01	0.00	0.20	0.17
09/09/99	0.00	0.72	0.00	0.00	0.00	0.02	0.17
09/10/99	0.00	0.65	0.00	0.00	0.00	0.05	1.69
09/11/99	0.00	0.67	0.00	0.00	0.00	0.05	1.50
09/12/99	0.00	0.65	0.00	0.00	0.00	0.05	1.38
09/13/99	0.00	0.58	0.00	0.00	0.00	0.02	1.10
09/14/99	0.00	0.58	0.00	0.00	0.00	0.05	0.94
09/15/99	0.00	0.55	0.00	0.00	0.00	0.05	0.63
09/16/99	0.00	0.53	0.00	0.00	0.00	0.04	0.49
09/17/99	0.00	0.49	0.00	0.00	0.00	0.02	0.33
09/18/99	0.00	0.49	0.00	0.00	0.00	0.00	0.17
09/19/99	0.00	0.45	0.00	0.00	0.00	0.04	0.00
09/20/99	0.00	0.44	0.00	0.00	0.00	0.04	0.00
09/21/99	0.00	0.43	0.00	0.00	0.00	0.00	0.00
09/22/99	0.00	0.43	0.00	0.00	0.00	0.00	0.00
09/23/99	0.00	0.52	0.00	0.00	0.00	0.00	0.00
09/24/99	0.00	0.55	0.00	0.00	0.00	0.00	0.00
09/25/99	0.00	0.53	0.00	0.00	0.00	0.05	0.00
09/26/99	0.00	0.54	0.00	0.00	0.00	0.05	0.00
09/27/99	0.00	0.48	0.00	0.00	0.00	0.20	0.00

daily flow data (CFS)

date	mc-7	mc-6	mc-5	mc-4	mc-3	mc-2	mc-1
09/28/99	0.00	0.43	0.00	0.00	0.00	0.29	0.00
09/29/99	0.00	0.41	0.00	0.00	0.00	0.12	0.00
09/30/99	0.00	0.41	0.00	0.00	0.00	0.00	0.00
10/01/99	0.00	0.76	0.00	0.00	0.00	0.05	0.00
10/02/99	0.00	0.76	0.00	0.00	0.00	0.16	0.00
10/03/99	0.00	0.79	0.00	0.00	0.00	0.56	0.00
10/04/99	0.00	0.78	0.00	0.00	0.00	0.63	0.00
10/05/99	0.00	0.68	0.00	0.00	0.00	0.56	0.00
10/06/99	0.00	0.65	0.00	0.00	0.00	0.39	0.00
10/07/99	0.00	0.72	0.00	0.00	0.00	0.29	0.00
10/08/99	0.00	0.67	0.00	0.00	0.00	0.24	0.00
10/09/99	0.00	0.59	0.00	0.00	0.00	0.20	0.00
10/10/99	0.00	0.52	0.00	0.00	0.00	0.16	0.00
10/11/99	0.00	0.49	0.00	0.00	0.00	0.12	0.00
10/12/99	0.00	0.50	0.00	0.00	0.00	0.12	0.00
10/13/99	0.00	0.52	0.00	0.00	0.00	0.05	0.00
10/14/99	0.00	0.57	0.00	0.00	0.00	0.05	0.00
10/15/99	0.00	0.60	0.00	0.00	0.00	0.08	0.00
10/16/99	0.00	0.56	0.00	0.00	0.00	0.08	0.00
10/17/99	0.00	0.55	0.00	0.00	0.00	0.05	0.00
10/18/99	0.00	0.62	0.00	0.00	0.00	0.08	0.00
10/19/99	0.00	0.65	0.00	0.00	0.00	0.12	0.00
10/20/99	0.00	0.67	0.00	0.00	0.00	0.16	0.00
10/21/99	0.00	0.65	0.00	0.00	0.00	0.16	0.00
10/22/99	0.00	0.61	0.00	0.00	0.00	0.12	0.00
10/23/99	0.00	0.60	0.00	0.00	0.00	0.08	0.00
10/24/99	0.00	0.65	0.00	0.00	0.00	0.05	0.00
10/25/99	0.00	0.66	0.00	0.00	0.00	0.08	0.00
10/26/99	0.00	0.68	0.00	0.00	0.00	0.16	0.00
10/27/99	0.00	0.71	0.00	0.00	0.00	0.20	0.00
10/28/99	0.00	0.69	0.00	0.00	0.00	0.16	0.00
10/29/99	0.00	0.80	0.00	0.00	0.00	0.16	0.00
10/30/99	0.00	0.84	0.00	0.00	0.00	0.20	0.00
10/31/99	0.00	0.97	0.00	0.00	0.00	0.20	0.00
11/01/99	0.00	0.75	0.00	0.00	0.00	0.24	0.00
11/02/99	0.00	0.70	0.00	0.02	0.00	0.29	0.00
11/03/99	0.00	0.69	0.00	0.00	0.00	0.34	0.00
11/04/99	0.00	0.75	0.00	0.00	0.00	0.39	0.00
11/05/99	0.00	0.72	0.00	0.00	0.00	0.45	0.00
11/06/99	0.00	0.69	0.00	0.00	0.00	0.51	0.00
11/07/99	0.00	0.69	0.00	0.00	0.00	0.56	0.00
11/08/99	0.00	0.74	0.00	0.00	0.00	0.63	0.00
11/09/99	0.00	0.71	0.00	0.00	0.00	0.69	0.00
11/10/99	0.00	0.68	0.00	0.00	0.00	0.75	0.00
11/11/99	0.00	0.66	0.00	0.01	0.00	0.82	0.00
11/12/99	0.00	0.68	0.00	0.03	0.00	0.89	0.00
11/13/99	0.00	0.68	0.00	0.08	0.00	0.95	0.00

daily flow data (CFS)

date	mc-7	mc-6	mc-5	mc-4	mc-3	mc-2	mc-1
11/14/99	0.00	0.66	0.00	0.15	0.00	1.02	0.00
11/15/99	0.00	0.64	0.00	0.22	0.00	1.09	0.00
11/16/99	0.00	0.57	0.00	0.00	0.00	1.16	0.00
11/17/99	0.00	0.59	0.00	0.00	0.00	0.00	0.00
11/18/99	0.00	0.61	0.00	0.00	0.00	0.00	0.00
11/19/99	0.00	0.64	0.00	0.00	0.00	0.00	0.00
11/20/99	0.00	0.66	0.00	0.00	0.00	0.00	0.00
11/21/99	0.00	0.68	0.00	0.00	0.00	0.00	0.00
11/22/99	0.00	0.70	0.00	0.00	0.00	0.00	0.00
11/23/99	0.00	0.73	0.00	0.00	0.00	0.00	0.00
11/24/99	0.00	0.75	0.00	0.00	0.00	0.00	0.00
11/25/99	0.00	0.77	0.00	0.00	0.00	0.00	0.00
11/26/99	0.00	0.80	0.00	0.00	0.00	0.00	0.00
11/27/99	0.00	0.82	0.00	0.00	0.00	0.00	0.00
11/28/99	0.00	0.84	0.00	0.00	0.00	0.00	0.00
11/29/99	0.00	0.87	0.00	0.00	0.00	0.00	0.00
11/30/99	0.00	0.89	0.00	0.00	0.00	0.00	0.00
12/01/99	0.00	0.91	0.00	0.00	0.00	0.00	0.00
12/02/99	0.00	0.93	0.00	0.00	0.00	0.00	0.00
12/03/99	0.00	0.96	0.00	0.00	0.00	0.00	0.00
12/04/99	0.00	0.98	0.00	0.00	0.00	0.00	0.00
12/05/99	0.00	1.00	0.00	0.00	0.00	0.00	0.00
12/06/99	0.00	1.03	0.00	0.00	0.00	0.00	0.00
12/07/99	0.00	1.05	0.00	0.00	0.00	0.00	0.00
12/08/99	0.00	2.32	0.00	0.00	0.00	0.00	0.00
12/09/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/10/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/11/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/12/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/13/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/14/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/15/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/16/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/17/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/18/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/19/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/20/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/21/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/22/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/23/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/24/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/25/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/26/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/27/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/28/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/29/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/30/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00

daily flow data (CFS)

date	mc-7	mc-6	mc-5	mc-4	mc-3	mc-2	mc-1
12/31/99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/01/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/02/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/03/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/04/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/05/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/06/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/07/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/08/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/09/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/10/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/11/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/12/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/13/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/14/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/15/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/16/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/17/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/18/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/19/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/20/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/21/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/22/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/23/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/24/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/25/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/26/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/27/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/28/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/29/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/30/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/31/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/01/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/02/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/03/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/04/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/05/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/06/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/07/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/08/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/09/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/10/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/11/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/12/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/13/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/14/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/15/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

daily flow data (CFS)

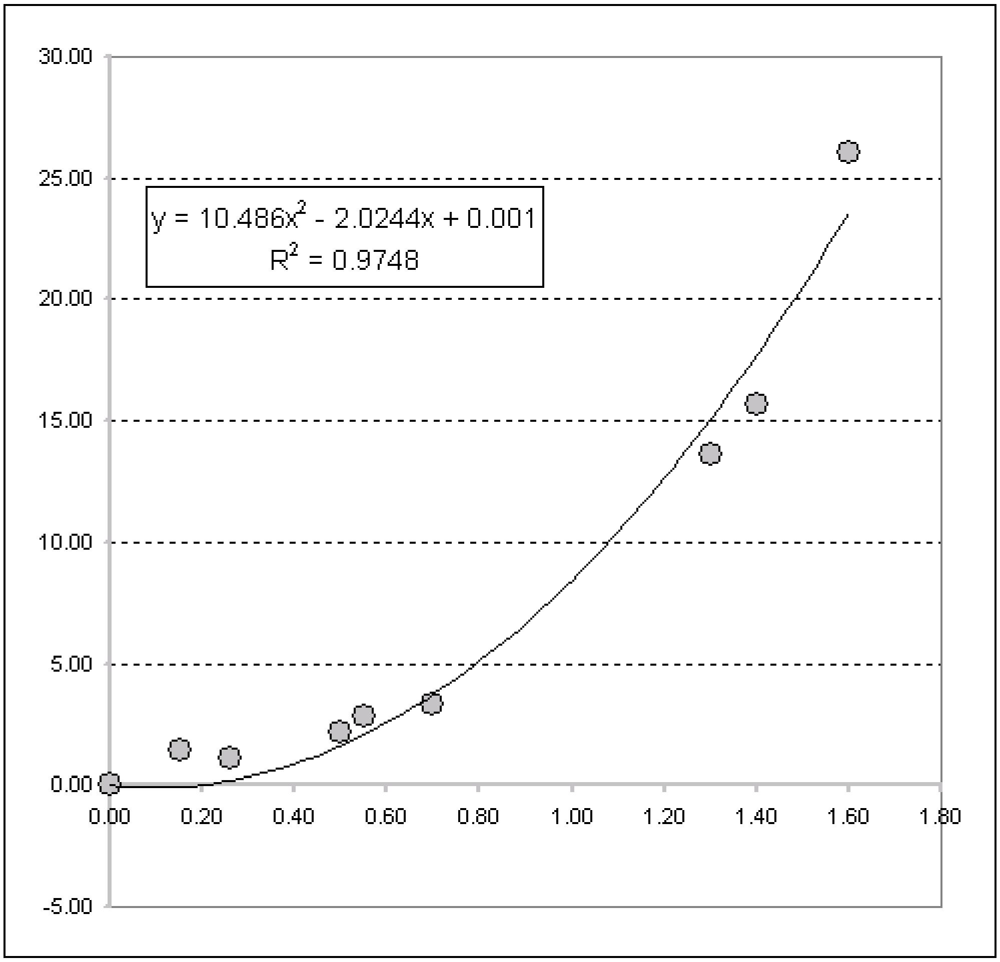
date	mc-7	mc-6	mc-5	mc-4	mc-3	mc-2	mc-1
02/16/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/17/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/18/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/19/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/20/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/21/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/22/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/23/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/24/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/25/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/26/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/27/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/28/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/29/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
03/01/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
03/02/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
03/03/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
03/04/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
03/05/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
03/06/00	0.00	2.19	2.44	0.16	0.00	1.59	0.00
03/07/00	0.00	2.10	2.67	0.92	0.00	1.59	0.00
03/08/00	0.00	4.12	3.17	1.38	0.00	2.16	0.76
03/09/00	0.00	12.06	4.00	1.12	0.00	2.50	1.43
03/10/00	0.00	9.22	2.92	0.52	0.00	1.45	1.43
03/11/00	0.00	8.90	3.26	0.37	0.00	0.69	1.69
03/12/00	0.00	8.56	3.26	0.37	0.00	0.45	1.94
03/13/00	0.00	9.36	3.35	1.59	0.00	0.45	1.85
03/14/00	0.00	9.63	2.92	0.11	0.00	0.24	1.62
03/15/00	0.00	9.60	2.92	0.00	0.00	0.39	1.50
03/16/00	0.00	8.73	2.76	0.12	0.00	0.16	1.50
03/17/00	0.00	9.13	2.60	0.69	0.00	0.08	1.50
03/18/00	0.00	7.48	2.67	1.57	0.00	0.02	1.38
03/19/00	0.00	7.54	2.67	3.99	0.00	0.02	1.20
03/20/00	0.00	6.99	2.67	3.45	0.00	0.05	0.94
03/21/00	0.00	7.80	2.76	2.16	0.00	0.05	0.76
03/22/00	0.00	8.35	2.84	1.10	0.00	0.05	0.76
03/23/00	0.00	8.54	2.84	2.03	0.00	0.02	0.76
03/24/00	0.00	9.10	2.92	3.41	0.00	0.75	0.94
03/25/00	0.00	9.35	3.17	2.16	0.00	0.75	0.76
03/26/00	0.00	9.20	3.26	3.02	0.00	0.29	1.00
03/27/00	0.00	9.35	3.35	2.38	0.00	0.12	1.15
03/28/00	0.00	8.96	3.17	1.80	0.00	0.05	1.15
03/29/00	0.00	8.71	3.53	1.81	0.00	0.02	1.05
03/30/00	0.00	8.87	3.53	1.78	0.00	0.00	0.88
03/31/00	0.00	8.63	3.44	1.56	0.00	0.05	0.63
04/01/00	0.00	8.20	3.35	1.16	0.00	0.02	0.41
04/02/00	0.00	8.00	3.17	1.12	0.00	0.02	0.33

daily flow data (CFS)

date	mc-7	mc-6	mc-5	mc-4	mc-3	mc-2	mc-1
04/03/00	0.00	7.72	3.35	1.15	0.00	0.05	0.17
04/04/00	0.00	7.11	3.53	0.90	0.00	0.02	0.00
04/05/00	0.00	6.91	3.09	1.56	0.00	0.05	0.00
04/06/00	0.00	6.69	3.35	0.99	0.00	0.00	0.00
04/07/00	0.00	5.44	3.44	0.71	0.00	0.05	0.00
04/08/00	0.00	4.07	3.53	1.81	0.00	0.03	0.00
04/09/00	0.00	5.75	3.53	2.00	0.00	0.16	0.00
04/10/00	0.00	5.98	3.62	1.76	0.00	0.08	0.00
04/11/00	0.00	6.29	3.62	1.55	0.00	0.00	0.00
04/12/00	0.00	6.35	3.72	1.43	0.00	0.05	0.00
04/13/00	0.00	6.59	3.91	1.20	0.00	0.04	0.00
04/14/00	0.00	6.30	4.10	1.17	0.00	0.05	0.00
04/15/00	0.00	6.11	4.30	1.29	0.00	0.05	0.00
04/16/00	0.00	6.38	4.51	1.04	0.00	0.05	0.09
04/17/00	0.00	6.62	4.72	1.79	0.00	0.20	0.25
04/18/00	0.00	6.89	4.93	1.95	0.00	1.09	0.69
04/19/00	0.00	8.17	6.19	2.76	0.00	2.50	1.50
04/20/00	0.00	9.67	6.68	6.02	1.19	3.78	4.90
04/21/00	0.00	14.51	7.07	8.60	0.00	2.69	10.28
04/22/00	0.00	17.55	7.07	9.90	0.00	1.59	3.90
04/23/00	0.00	18.15	5.83	12.44	0.00	0.95	2.40
04/24/00	0.00	18.33	5.04	14.41	0.00	0.69	1.91
04/25/00	0.09	16.00	4.72	17.00	0.00	0.45	1.62
04/26/00	0.09	14.93	4.20	20.00	0.00	0.29	1.88
04/27/00	0.09	15.96	4.30	26.30	0.00	0.34	1.78
04/28/00	0.68	15.75	4.40	19.50	0.00	0.34	1.58
04/29/00	2.30	13.45	4.40	14.63	0.00	0.24	1.38
04/30/00	1.58	11.28	4.72	11.40	0.00	0.75	1.50
05/01/00	4.00	11.03	4.93	12.83	0.00	1.38	1.58
05/02/00	4.95	11.18	5.04	12.50	0.00	1.16	1.54
05/03/00	4.95	10.51	5.37	12.62	0.00	0.75	1.50
05/04/00	7.06	9.64	5.83	11.92	0.00	0.45	1.62
05/05/00	7.63	9.06	6.07	10.79	0.00	0.20	1.34
05/06/00	4.47	9.15	5.95	8.80	0.00	0.02	1.05
05/07/00	4.47	11.10	6.43	7.16	0.00	0.20	1.50
05/08/00	4.95	9.26	5.60	7.19	0.00	2.16	2.15
05/09/00	5.98	11.22	5.15	8.43	0.00	2.50	2.68
05/10/00	5.46	9.51	4.72	7.19	0.00	2.02	2.76
05/11/00	6.51	8.23	4.93	9.00	0.00	1.74	2.63
05/12/00	4.47	7.80	4.72	11.52	0.00	1.30	2.21
05/13/00	3.55	8.18	4.82	12.27	0.00	0.75	1.85
05/14/00	4.00	7.90	4.93	10.93	0.00	0.75	1.58
05/15/00	4.00	7.47	5.37	11.92	0.00	0.69	1.43

MC-1 Discharge Table

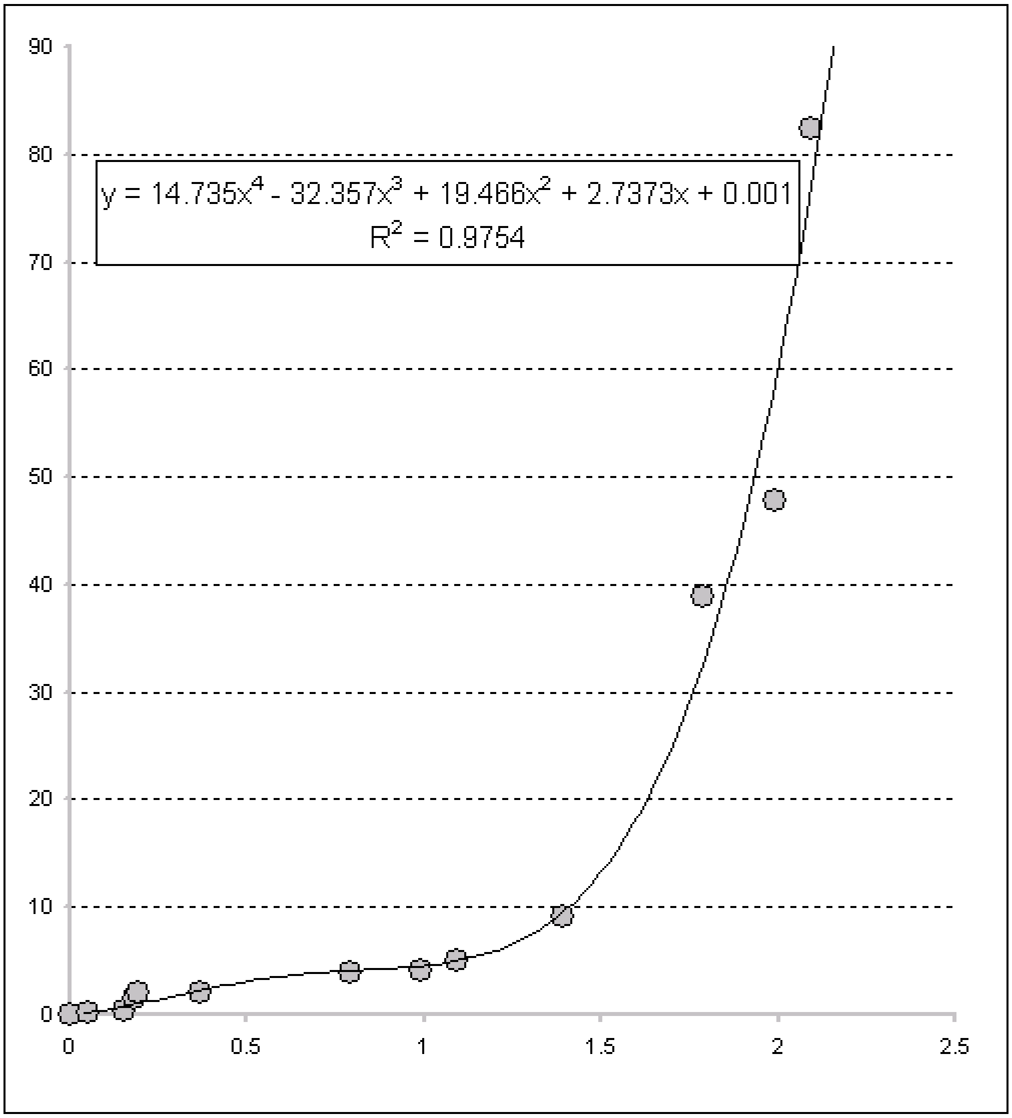
Stage	Flow
0.00	0.00
0.15	1.46
0.26	1.11
0.50	2.15
0.55	2.79
0.70	3.35
1.30	13.65
1.40	15.66
1.60	26.03



Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge
0.00	0.00	0.50	1.61	1.00	8.46	1.50	20.56
0.03	-0.04	0.53	1.83	1.03	8.94	1.53	21.30
0.05	-0.07	0.55	2.06	1.05	9.44	1.55	22.06
0.08	-0.09	0.58	2.30	1.08	9.94	1.58	22.82
0.10	-0.10	0.60	2.56	1.10	10.46	1.60	23.61
0.13	-0.09	0.63	2.83	1.13	10.99	1.63	24.40
0.15	-0.07	0.65	3.12	1.15	11.54	1.65	25.21
0.18	-0.03	0.68	3.41	1.18	12.10	1.68	26.03
0.20	0.02	0.70	3.72	1.20	12.67	1.70	26.86
0.23	0.08	0.73	4.05	1.23	13.26	1.73	27.71
0.25	0.15	0.75	4.38	1.25	13.85	1.75	28.57
0.28	0.24	0.78	4.73	1.28	14.47	1.78	29.45
0.30	0.34	0.80	5.09	1.30	15.09	1.80	30.33
0.33	0.45	0.83	5.47	1.33	15.73	1.83	31.23
0.35	0.58	0.85	5.86	1.35	16.38	1.85	32.14
0.38	0.72	0.88	6.26	1.38	17.04	1.88	33.07
0.40	0.87	0.90	6.67	1.40	17.72	1.90	34.01
0.43	1.03	0.93	7.10	1.43	18.41	1.93	34.96
0.45	1.21	0.95	7.54	1.45	19.11	1.95	35.93
0.48	1.41	0.98	8.00	1.48	19.83	1.98	36.90

MC-2 Discharge Table

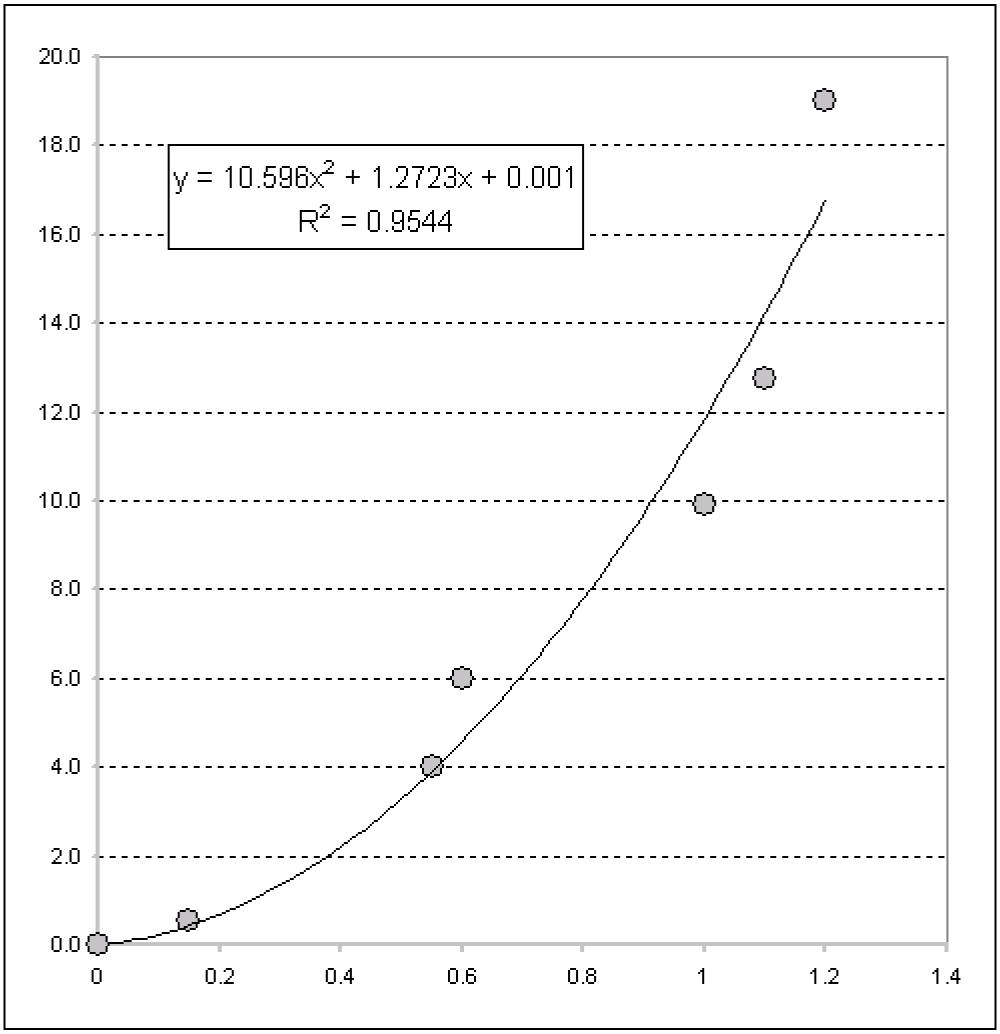
Stage	Flow
0	0
0.05	0.2
0.15	0.43
0.18	1.58
0.19	2
0.37	2
0.79	3.82
0.99	4.04
1.09	4.94
1.39	9.18
1.79	38.81
1.99	47.71
2.09	82.42



Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge
0.00	0.00	0.75	4.02	1.50	13.30	2.25	113.78
0.05	0.18	0.80	4.12	1.55	15.57	2.30	127.93
0.10	0.44	0.85	4.21	1.60	18.25	2.35	143.40
0.15	0.75	0.90	4.31	1.65	21.38	2.40	160.26
0.20	1.09	0.95	4.43	1.70	25.01	2.45	178.61
0.25	1.45	1.00	4.58	1.75	29.19	2.50	198.51
0.30	1.82	1.05	4.79	1.80	33.97	2.55	220.07
0.35	2.18	1.10	5.07	1.85	39.41	2.60	243.36
0.40	2.52	1.15	5.45	1.90	45.57	2.65	268.47
0.45	2.83	1.20	5.96	1.95	52.49	2.70	295.49
0.50	3.11	1.25	6.62	2.00	60.24	2.75	324.53
0.55	3.36	1.30	7.45	2.05	68.89	2.80	355.67
0.60	3.57	1.35	8.51	2.10	78.50	2.85	389.02
0.65	3.75	1.40	9.80	2.15	89.14	2.90	424.67
0.70	3.89	1.45	11.39	2.20	100.88	2.95	462.73

MC-3 Discharge Table

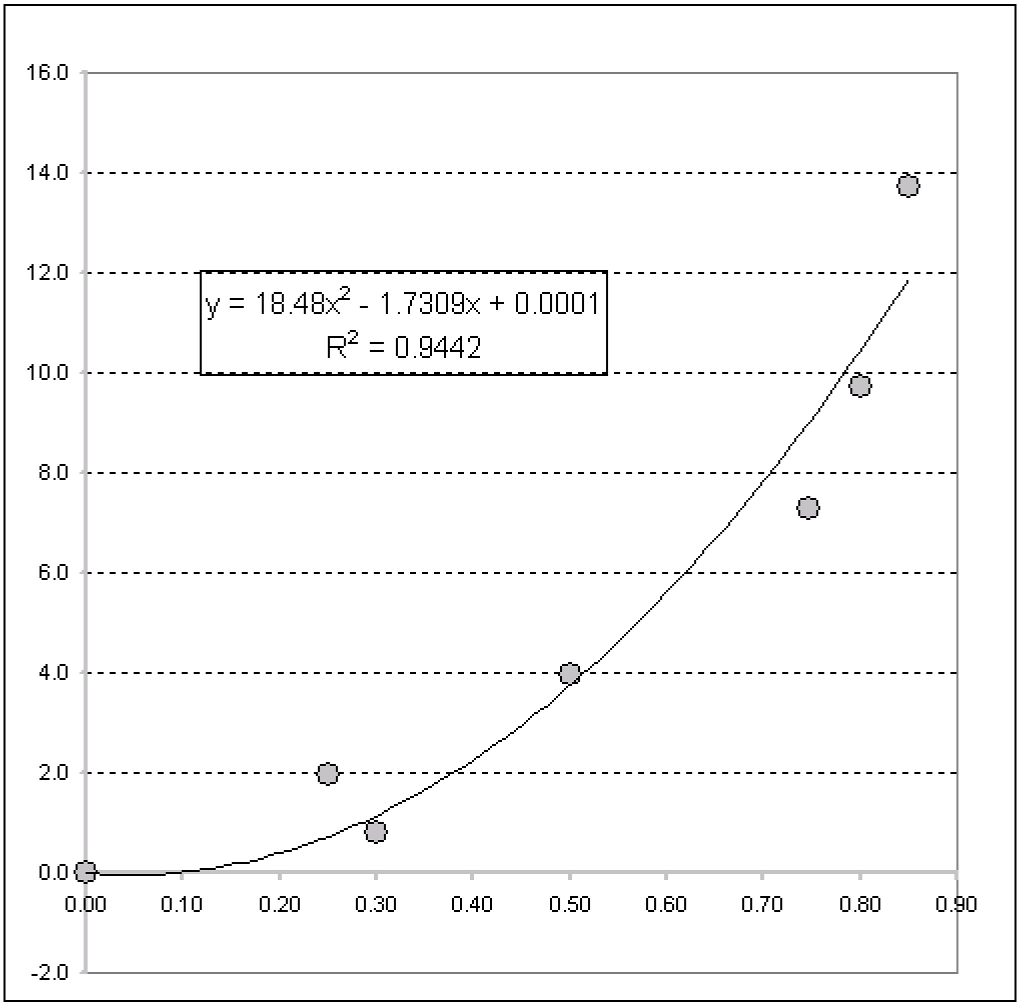
Stage	Flow
0	0
0.15	0.53
0.55	4.00
0.60	5.98
1.00	9.92
1.10	12.73
1.20	19.02



Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge
0.00	0.00	0.36	1.83	0.72	6.41	1.08	13.73
0.02	0.03	0.38	2.01	0.74	6.74	1.10	14.22
0.04	0.07	0.40	2.21	0.76	7.09	1.12	14.72
0.06	0.12	0.42	2.40	0.78	7.44	1.14	15.22
0.08	0.17	0.44	2.61	0.80	7.80	1.16	15.73
0.10	0.23	0.46	2.83	0.82	8.17	1.18	16.26
0.12	0.31	0.48	3.05	0.84	8.55	1.20	16.79
0.14	0.39	0.50	3.29	0.86	8.93	1.22	17.32
0.16	0.48	0.52	3.53	0.88	9.33	1.24	17.87
0.18	0.57	0.54	3.78	0.90	9.73	1.26	18.43
0.20	0.68	0.56	4.04	0.92	10.14	1.28	18.99
0.22	0.79	0.58	4.30	0.94	10.56	1.30	19.56
0.24	0.92	0.60	4.58	0.96	10.99	1.32	20.14
0.26	1.05	0.62	4.86	0.98	11.42	1.34	20.73
0.28	1.19	0.64	5.16	1.00	11.87	1.36	21.33
0.30	1.34	0.66	5.46	1.02	12.32	1.38	21.94
0.32	1.49	0.68	5.77	1.04	12.78	1.40	22.55
0.34	1.66	0.70	6.08	1.06	13.26	1.42	23.17

MC-4 Discharge Table

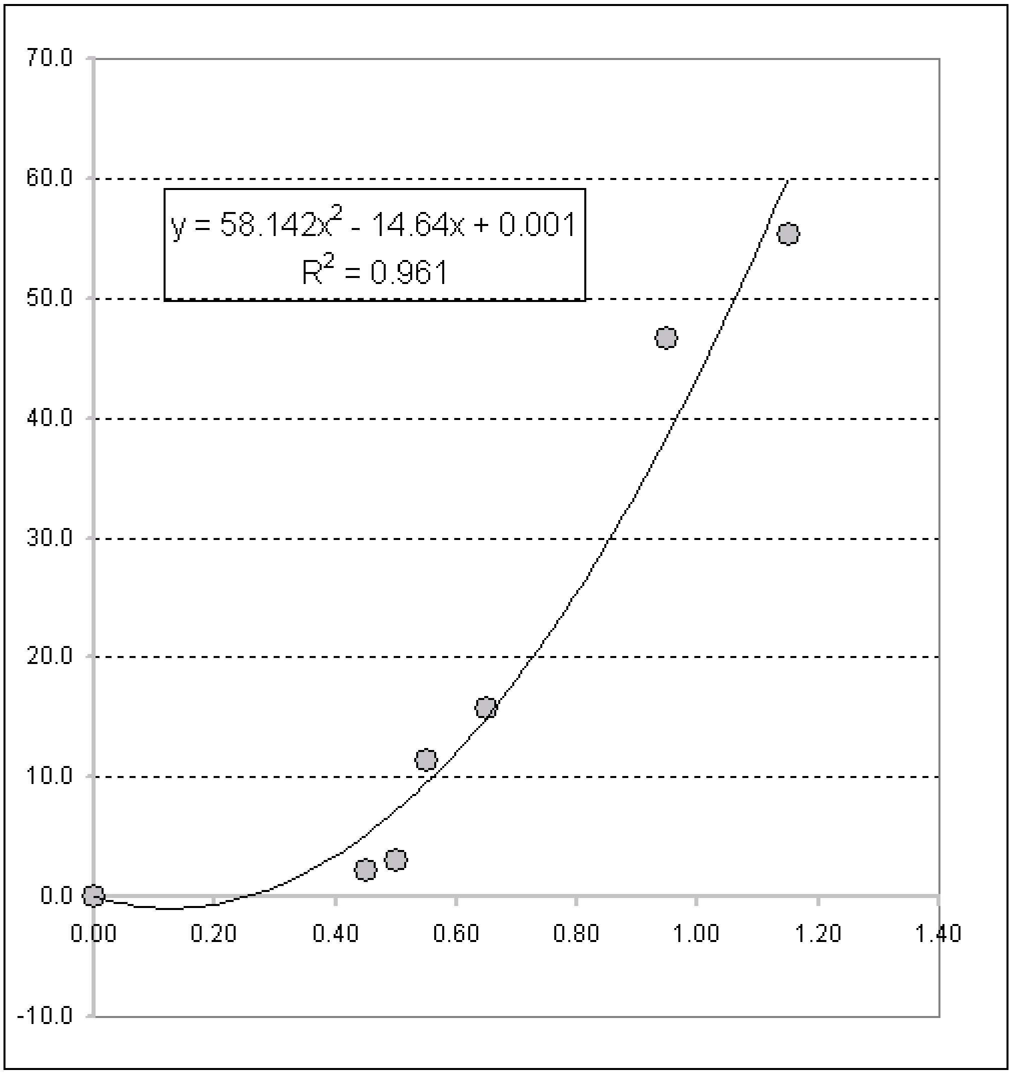
Stage	Flow
0.00	0.00
0.30	0.81
0.25	1.95
0.50	3.95
0.75	7.27
0.80	9.72
0.85	13.74



Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge
0.00	0.00	0.36	1.77	0.72	8.33	1.08	19.69
0.02	-0.03	0.38	2.01	0.74	8.84	1.10	20.46
0.04	-0.04	0.40	2.26	0.76	9.36	1.12	21.24
0.06	-0.04	0.42	2.53	0.78	9.89	1.14	22.04
0.08	-0.02	0.44	2.82	0.80	10.44	1.16	22.86
0.10	0.01	0.46	3.11	0.82	11.01	1.18	23.69
0.12	0.06	0.48	3.43	0.84	11.59	1.20	24.53
0.14	0.12	0.50	3.75	0.86	12.18	1.22	25.39
0.16	0.20	0.52	4.10	0.88	12.79	1.24	26.27
0.18	0.29	0.54	4.45	0.90	13.41	1.26	27.16
0.20	0.39	0.56	4.83	0.92	14.05	1.28	28.06
0.22	0.51	0.58	5.21	0.94	14.70	1.30	28.98
0.24	0.65	0.60	5.61	0.96	15.37	1.32	29.91
0.26	0.80	0.62	6.03	0.98	16.05	1.34	30.86
0.28	0.96	0.64	6.46	1.00	16.75	1.36	31.83
0.30	1.14	0.66	6.91	1.02	17.46	1.38	32.80
0.32	1.34	0.68	7.37	1.04	18.19	1.40	33.80
0.34	1.55	0.70	7.84	1.06	18.93	1.42	34.81

MC-5 1999 Discharge Table

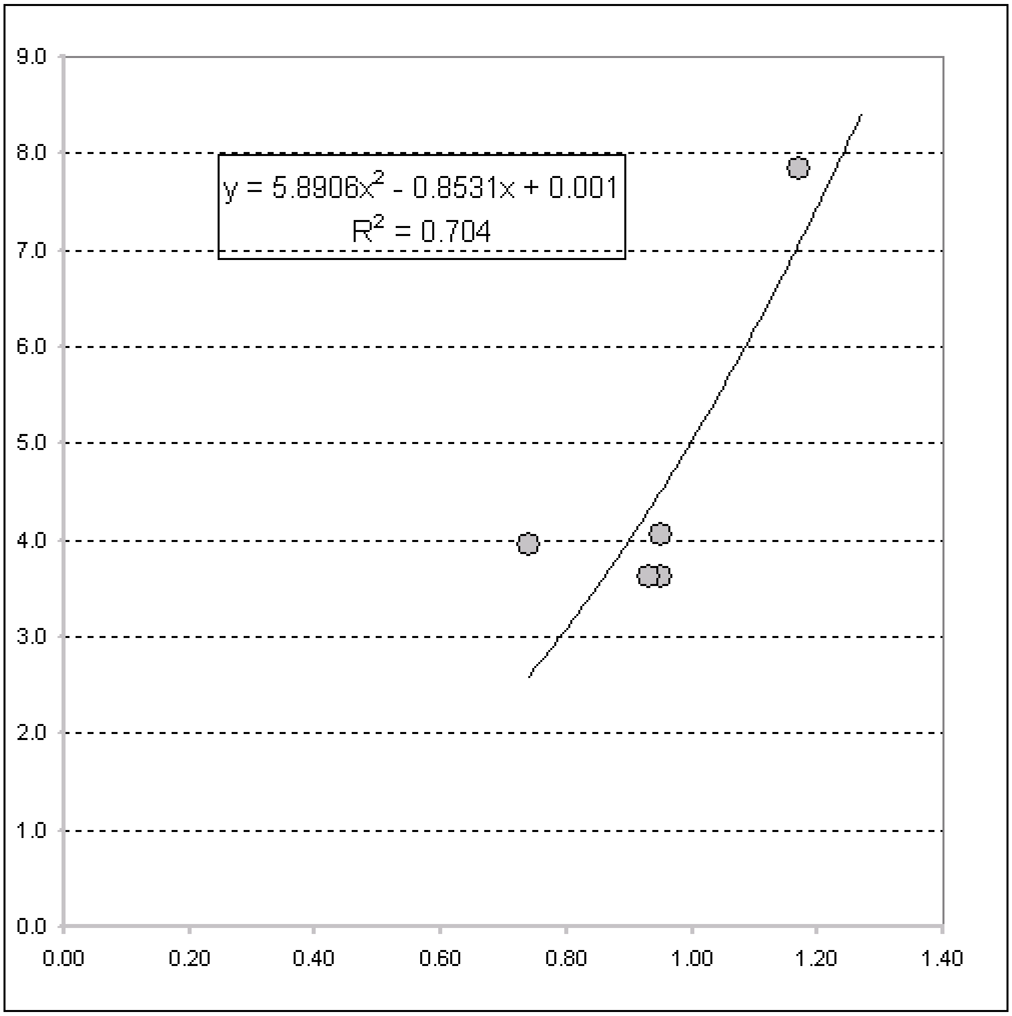
Stage	Flow
0.00	0.00
0.45	2.19
0.50	2.98
0.55	11.31
0.65	15.69
0.95	46.61
1.15	55.22



Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge
0.00	0.00	0.40	3.45	0.80	25.50	1.20	66.16
0.03	-0.33	0.43	4.28	0.83	27.50	1.23	69.32
0.05	-0.59	0.45	5.19	0.85	29.56	1.25	72.55
0.08	-0.77	0.48	6.17	0.88	31.71	1.28	75.85
0.10	-0.88	0.50	7.22	0.90	33.92	1.30	79.23
0.13	-0.92	0.53	8.34	0.93	36.21	1.33	82.68
0.15	-0.89	0.55	9.54	0.95	38.57	1.35	86.20
0.18	-0.78	0.58	10.81	0.98	41.00	1.38	89.80
0.20	-0.60	0.60	12.15	1.00	43.50	1.40	93.46
0.23	-0.35	0.63	13.56	1.03	46.08	1.43	97.20
0.25	-0.03	0.65	15.05	1.05	48.73	1.45	101.02
0.28	0.37	0.68	16.61	1.08	51.45	1.48	104.90
0.30	0.84	0.70	18.24	1.10	54.25	1.50	108.86
0.33	1.38	0.73	19.95	1.13	57.12	1.53	112.89
0.35	2.00	0.75	21.73	1.15	60.06	1.55	117.00
0.38	2.69	0.78	23.58	1.18	63.07	1.58	121.17

MC-5 2000 Discharge Table

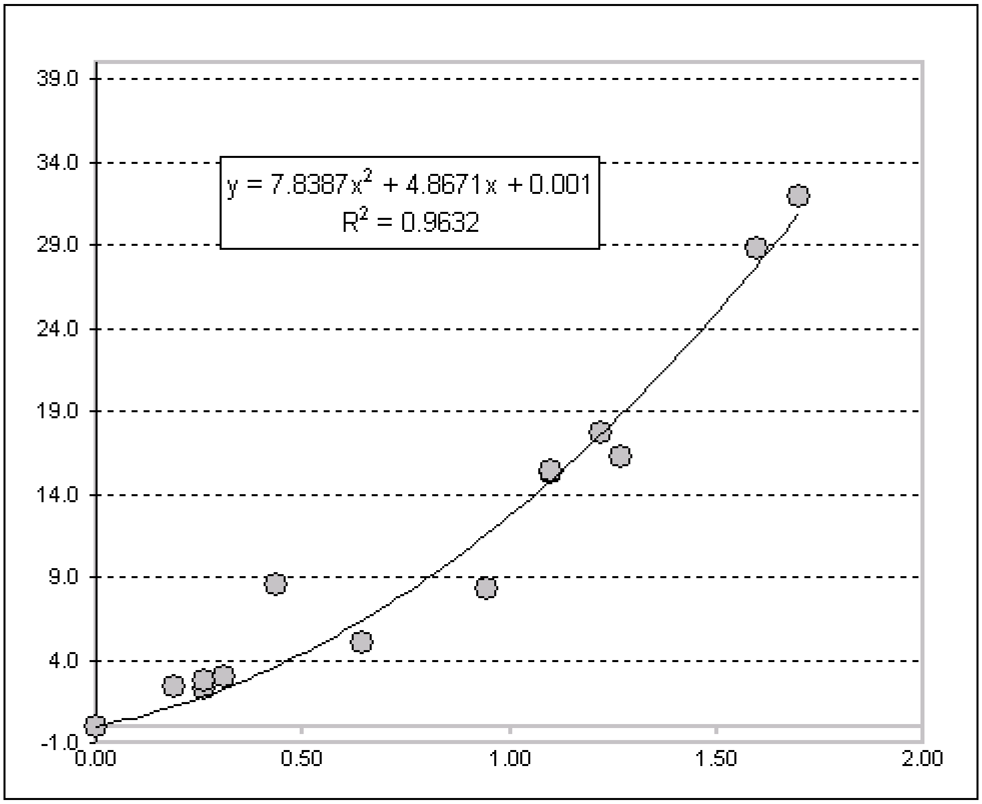
Stage	Flow
0.95	4.06
0.95	3.62
0.74	3.95
1.17	7.84
0.93	3.62



Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge
0.70	2.29	0.84	3.44	0.98	4.82	1.12	6.43
0.71	2.36	0.85	3.53	0.99	4.93	1.13	6.56
0.72	2.44	0.86	3.62	1.00	5.04	1.14	6.68
0.73	2.52	0.87	3.72	1.01	5.15	1.15	6.81
0.74	2.60	0.88	3.81	1.02	5.26	1.16	6.94
0.75	2.67	0.89	3.91	1.03	5.37	1.17	7.07
0.76	2.76	0.90	4.00	1.04	5.49	1.18	7.20
0.77	2.84	0.91	4.10	1.05	5.60	1.19	7.33
0.78	2.92	0.92	4.20	1.06	5.72	1.20	7.46
0.79	3.00	0.93	4.30	1.07	5.83	1.21	7.59
0.80	3.09	0.94	4.40	1.08	5.95	1.22	7.73
0.81	3.17	0.95	4.51	1.09	6.07	1.23	7.86
0.82	3.26	0.96	4.61	1.10	6.19	1.24	8.00
0.83	3.35	0.97	4.72	1.11	6.31	1.25	8.14

MC-6 Discharge Table

Stage	Flow
0.00	0.00
0.26	2.29
0.19	2.33
0.26	2.79
0.31	2.94
0.64	5.05
0.94	8.24
0.44	8.52
1.10	15.22
1.10	15.34
1.27	16.27
1.22	17.74
1.60	28.74
1.70	31.93



Stage	Discharge
0.00	0.00
0.03	0.12
0.05	0.26
0.08	0.40
0.10	0.55
0.13	0.72
0.15	0.89
0.18	1.07
0.20	1.26
0.23	1.47
0.25	1.68
0.28	1.90
0.30	2.13
0.33	2.38
0.35	2.63
0.38	2.89
0.40	3.16
0.43	3.44
0.45	3.73
0.48	4.04

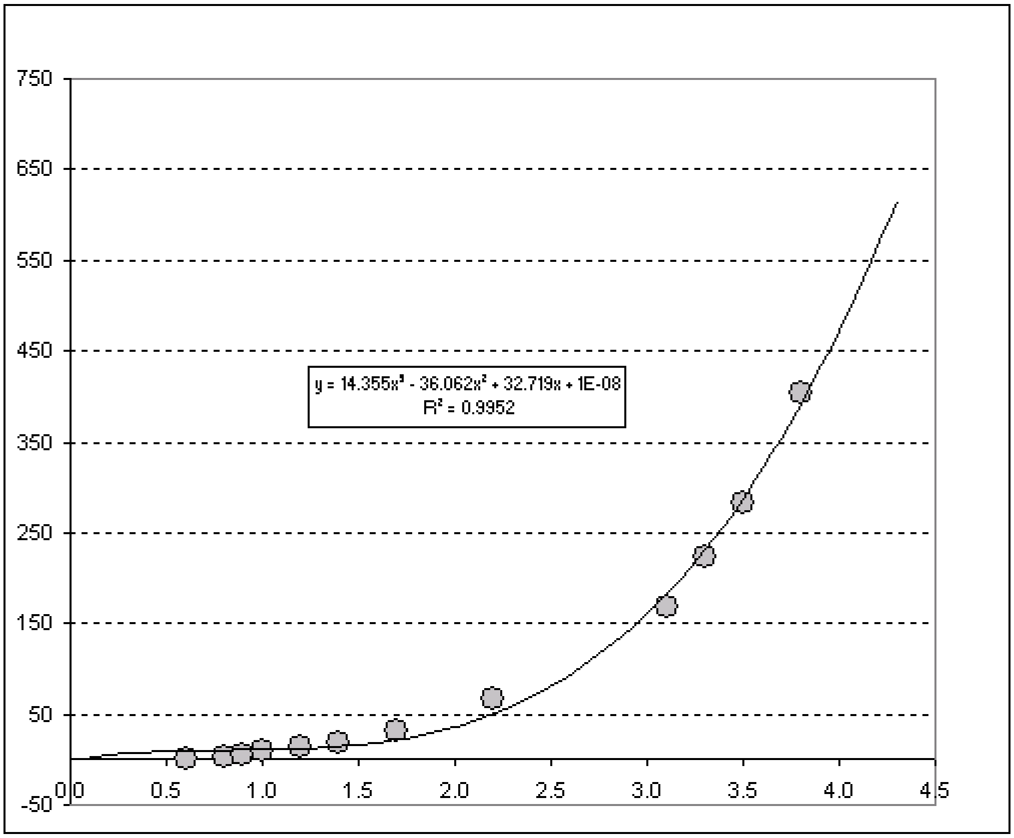
Stage	Discharge
0.50	4.35
0.53	4.67
0.55	5.00
0.58	5.34
0.60	5.69
0.63	6.05
0.65	6.42
0.68	6.80
0.70	7.19
0.73	7.59
0.75	8.00
0.78	8.42
0.80	8.85
0.83	9.29
0.85	9.74
0.88	10.20
0.90	10.67
0.93	11.15
0.95	11.64
0.98	12.14

Stage	Discharge
1.00	12.65
1.03	13.17
1.05	13.69
1.08	14.23
1.10	14.78
1.13	15.34
1.15	15.91
1.18	16.49
1.20	17.07
1.23	17.67
1.25	18.28
1.28	18.90
1.30	19.52
1.33	20.16
1.35	20.81
1.38	21.47
1.40	22.13
1.43	22.81
1.45	23.50
1.48	24.19

Stage	Discharge
1.50	24.90
1.53	25.62
1.55	26.34
1.58	27.08
1.60	27.83
1.63	28.58
1.65	29.35
1.68	30.12
1.70	30.91
1.73	31.71
1.75	32.51
1.78	33.33
1.80	34.15
1.83	34.99
1.85	35.83
1.88	36.69
1.90	37.55
1.93	38.43
1.95	39.31
1.98	40.20

MC-7 Discharge Table

Stage	Flow
0.60	1.20
0.80	2.00
0.90	5.58
1.00	8.80
1.20	14.22
1.40	17.78
1.70	30.60
2.20	66.33
3.10	169.11
3.30	222.26
3.50	283.50
3.80	404.13



Stage	Flow	Stage	Flow	Stage	Flow	Stage	Flow
0.00	0.00	1.25	12.59	2.50	80.71	3.75	372.58
0.05	1.55	1.30	13.13	2.55	86.97	3.80	391.28
0.10	2.93	1.35	13.77	2.60	93.59	3.85	410.63
0.15	4.14	1.40	14.52	2.65	100.60		
0.20	5.22	1.45	15.39	2.70	108.00		
0.25	6.15	1.50	16.39	2.75	115.80		
0.30	6.96	1.55	17.53	2.80	124.01		
0.35	7.65	1.60	18.83	2.85	132.64		
0.40	8.24	1.65	20.29	2.90	141.71		
0.45	8.73	1.70	21.93	2.95	151.22		
0.50	9.14	1.75	23.75	3.00	161.18		
0.55	9.48	1.80	25.77	3.05	171.62		
0.60	9.75	1.85	28.00	3.10	182.52		
0.65	9.97	1.90	30.44	3.15	193.92		
0.70	10.16	1.95	33.12	3.20	205.81		
0.75	10.31	2.00	36.03	3.25	218.21		
0.80	10.45	2.05	39.19	3.30	231.13		
0.85	10.57	2.10	42.62	3.35	244.58		
0.90	10.70	2.15	46.31	3.40	258.58		
0.95	10.84	2.20	50.29	3.45	273.12		
1.00	11.01	2.25	54.57	3.50	288.23		
1.05	11.21	2.30	59.14	3.55	303.91		
1.10	11.46	2.35	64.03	3.60	320.17		
1.15	11.77	2.40	69.25	3.65	337.03		
1.20	12.14	2.45	74.81	3.70	354.50		

Appendix F. Tributary Water Quality Sample Data

SITE	DATE	Time	SAMPLER	TYPE	Depth	Water Temp	Air Temp	Dissolved Oxygen	Conductivity	Turbidity	Field pH	Total Solids	Total Dissolved Solids	Total Suspended Solids
MC-1	06/08/1999	14:00	KRUGER	GRAB	SURFACE	26.60			2130		7.76	1591	1497	23
MC-1	06/14/1999	11:50	NIELSEN/KRUGER	GRAB	SURFACE	22.10		7.35			7.97	1511	1421	30
MC-1	06/29/1999	8:30	NIELSEN/KRUGER	GRAB	SURFACE	17.34		4.00		77.5	7.75	1927	1823	9
MC-1	03/15/2000	11:00	KRUGER	GRAB	SURFACE		15					2350	2243	7
MC-1	04/20/2000		KRUGER	GRAB	SURFACE							2965	2845	23
MC-2	06/08/1999	15:10	KRUGER	GRAB	SURFACE	26.30			1480		7.73	1144	1088	15
MC-2	06/14/1999	10:42	NIELSEN/KRUGER	GRAB	SURFACE	18.70		8.05			7.76	1324	1220	11
MC-2	06/29/1999	9:00	NIELSEN/KRUGER	GRAB	SURFACE	17.57		5.29		72.0	7.85	1391	1269	36
MC-2	09/08/1999	12:00	KRUGER	GRAB	SURFACE	14.53	65	9.36	1714	35.4	7.62	1878	1815	6
MC-2	09/28/1999	10:00	KRUGER	GRAB	SURFACE	8.91	50	10.60	1837	27.1	7.44	2031	1942	5
MC-2	11/16/1999	10:00	KRUGER	GRAB	SURFACE	13.00	38	11.95	1354		7.62	1614	1533	10
MC-2	03/07/2000	12:00	KRUGER	GRAB	SURFACE	8.44	55	13.08	1194	14.6	7.94	1173	1139	1
MC-2	03/15/2000	11:30	KRUGER	GRAB	SURFACE		15					1479	1410	3
MC-2	04/20/2000		KRUGER	GRAB	SURFACE							1491	1427	7
MC-3	06/08/1999	16:00	KRUGER	GRAB	SURFACE	29.60			1500		8.10	1257	1206	3
MC-3	04/20/2000		KRUGER	GRAB	SURFACE							2139	2051	15
MC-4	06/08/1999	16:30	KRUGER	GRAB	SURFACE	28.20			2490		8.26	1944	1810	70
MC-4	06/14/1999	16:25	NIELSEN/KRUGER	GRAB	SURFACE	24.30		8.80			8.26	1896	1742	60
MC-4	06/29/1999	10:00	NIELSEN/KRUGER	GRAB	SURFACE	19.52		4.16		385.0	8.29	2037	1935	76
MC-4	03/07/2000	11:00	KRUGER	GRAB	SURFACE	8.25	55	12.31	2627	141.0	8.27	2477	2359	62
MC-4	04/20/2000		KRUGER	GRAB	SURFACE							3109	2956	62
MC-4	04/27/2000		KRUGER	GRAB	SURFACE							3411	3122	78
MC-5	06/08/1999	17:00	KRUGER	GRAB	SURFACE	28.90			1560		7.99	1189	1125	30
MC-5	06/14/1999	15:40	NIELSEN/KRUGER	GRAB	SURFACE	25.40		6.15			8.11	1269	1169	29
MC-5	06/29/1999	12:00	NIELSEN/KRUGER	GRAB	SURFACE	20.00		6.27		254	8.31	1446	1345	68
MC-5	03/07/2000	10:00	KRUGER	GRAB	SURFACE	5.11	60	8.31	1456	60.8	7.99	1538	1467	7
MC-5	04/20/2000		KRUGER	GRAB	SURFACE							2085	1987	9
MC-5	36643.00		KRUGER	GRAB	SURFACE							3417	3184	76
MC-6	06/08/1999	18:00	KRUGER	GRAB	SURFACE	27.10			1860		8.15	1389	1353	80
MC-6	06/14/1999	14:55	NIELSEN/KRUGER	GRAB	SURFACE	23.10		9.60			8.17	1598	1435	90
MC-6	06/29/1999	13:30	NIELSEN/KRUGER	GRAB	SURFACE	22.20		11.04		130	8.48	1455	1367	52
MC-6	08/31/1999	7:20	KRUGER	GRAB	SURFACE	20.70	70	5.76	1500	233.2	8.04	1307	1194	66
MC-6	09/08/1999	14:00	KRUGER	GRAB	SURFACE	19.58	70	10.23	1270	238	8.22	1444	1331	76
MC-6	09/28/1999	12:00	KRUGER	GRAB	SURFACE	12.75	55	11.49	1514	147.5	7.91	1357	1269	30
MC-6	11/16/1999	12:00	KRUGER	GRAB	SURFACE	13.00	43	12.38	1215		7.70	1264	1187	30
MC-6	12/08/2000	12:45	SMITH/KRUGER	GRAB	SURFACE	4.00	25		1121		8.46	1343	1281	21
MC-6	03/06/2000	10:00	KRUGER	GRAB	SURFACE	7.49	60	12.69	891	133.2	7.99	854	800	26
MC-6	03/08/2000	9:15	KRUGER	GRAB	SURFACE	9.29	40	9.84	1183	124.3	7.93	1068	999	35
MC-6	04/27/2000		KRUGER	GRAB	SURFACE							2716	2375	212
MC-7	06/08/1999	18:30	KRUGER	GRAB	SURFACE	26.00			1680		8.70	1362	1202	108
MC-7	06/14/1999	14:10	NIELSEN/KRUGER	GRAB	SURFACE	23.00		9.70			8.38	1603	1211	27

MC-7	06/29/1999	14:45	NIELSEN/KRUGER	GRAB	SURFACE	23.22		8.50		92.7	8.66	1311	1254	24
MC-7	05/11/2000		NIELSEN/KRUGER	GRAB	SURFACE							1504	1432	19

SITE	DATE	Time	SAMPLER	TYPE	Depth	Total Alkalinity	Ammonia	Nitrate	TKN	Total Phosphorus	Total Dissolved Phosphorus	Fecal Coliforms	Total Volatile Suspended Solids
MC-1	06/08/1999	14:00	KRUGER	GRAB	SURFACE	312	<0.02	<0.1	3.10	1.01	0.927		
MC-1	06/14/1999	11:50	NIELSEN/KRUGER	GRAB	SURFACE	401	<0.02	<0.1	3.27	1.10	1.02	630	
MC-1	06/29/1999	8:30	NIELSEN/KRUGER	GRAB	SURFACE	422	<.02	<.1	3.05	1.05	.949	9000	
MC-1	03/15/2000	11:00	KRUGER	GRAB	SURFACE	309	0.01	0.05	1.86	0.174	0.062	5	
MC-1	04/20/2000		KRUGER	GRAB	SURFACE	375	0.02	0.1	2.59	0.243	0.155	20	8
MC-2	06/08/1999	15:10	KRUGER	GRAB	SURFACE	361	0.02	0.1	2.07	1.29	1.20		
MC-2	06/14/1999	10:42	NIELSEN/KRUGER	GRAB	SURFACE	395	<0.02	0.1	2.01	1.27	1.23	190	
MC-2	06/29/1999	9:00	NIELSEN/KRUGER	GRAB	SURFACE	395	<.02	.1	1.88	.952	.843	740	
MC-2	09/08/1999	12:00	KRUGER	GRAB	SURFACE	362	<.02	<.1	1	.182	.147	340	2
MC-2	09/28/1999	10:00	KRUGER	GRAB	SURFACE	358	<.02	<.1	1.58	0.121	0.081	1000	<1
MC-2	11/16/1999	10:00	KRUGER	GRAB	SURFACE	401	<.02	<.1	0.56	0.097	0.057	10	1
MC-2	03/07/2000	12:00	KRUGER	GRAB	SURFACE	321	0.01	0.05	0.74	0.135	0.087	1	1
MC-2	03/15/2000	11:30	KRUGER	GRAB	SURFACE	395	0.01	0.05	0.70	0.080	0.064	5	1
MC-2	04/20/2000		KRUGER	GRAB	SURFACE	356	0.02	0.3	1.36	0.296	0.184	1000	3
MC-3	06/08/1999	16:00	KRUGER	GRAB	SURFACE	310	<0.02	<0.1	1.49	0.339	0.315		
MC-3	04/20/2000		KRUGER	GRAB	SURFACE	281	0.43	1.6	2.49	0.658	0.594	100	2
MC-4	06/08/1999	16:30	KRUGER	GRAB	SURFACE	405	<0.02	<0.1	2.98	0.836	0.583		
MC-4	06/14/1999	16:25	NIELSEN/KRUGER	GRAB	SURFACE	399	0.10	<0.1	2.98	0.817	0.645	930	
MC-4	06/29/1999	10:00	NIELSEN/KRUGER	GRAB	SURFACE	446	0.15	0.1	3.81	0.682	0.483	5900	
MC-4	03/07/2000	11:00	KRUGER	GRAB	SURFACE	275	0.09	0.3	4.43	0.688	0.194	5	26
MC-4	04/20/2000		KRUGER	GRAB	SURFACE	269	0.02	0.2	2.59	0.296	0.043	130000	10
MC-4	04/27/2000		KRUGER	GRAB	SURFACE	409	0.01	0.05	3.56	0.363	0.108	2600	22
MC-5	06/08/1999	17:00	KRUGER	GRAB	SURFACE	355	<0.02	<.1	2.59	0.969	0.858		
MC-5	06/14/1999	15:40	NIELSEN/KRUGER	GRAB	SURFACE	416	<0.02	0.1	2.25	0.889	0.802	340	
MC-5	06/29/1999	12:00	NIELSEN/KRUGER	GRAB	SURFACE	466	<.02	<.1	2.81	1.05	.842	2100	
MC-5	03/07/2000	10:00	KRUGER	GRAB	SURFACE	313	0.02	0.1	1.66	0.437	0.337	90	3
MC-5	04/20/2000		KRUGER	GRAB	SURFACE	388	0.02	0.4	1.55	0.266	0.189	600	3
MC-5	04/27/2000		KRUGER	GRAB	SURFACE	412	0.01	0.05	3.45	0.366	0.111	3000	22
MC-6	06/08/1999	18:00	KRUGER	GRAB	SURFACE	404	<0.02	<0.1	2.59	0.757	0.500		
MC-6	06/14/1999	14:55	NIELSEN/KRUGER	GRAB	SURFACE	424	<0.02	<0.1	2.51	0.734	0.535	410	
MC-6	06/29/1999	13:30	NIELSEN/KRUGER	GRAB	SURFACE	414	<.02	.1	2.24	.486	.258	2200	
MC-6	08/31/1999	7:20	KRUGER	GRAB	SURFACE	329	.06	.1	1.09	.238	.098	720	16
MC-6	09/08/1999	14:00	KRUGER	GRAB	SURFACE	363	<.02	<.1	1.32	.285	.061	190	14
MC-6	09/28/1999	12:00	KRUGER	GRAB	SURFACE	356	<.02	<.1	1.43	0.186	0.060	230	3
MC-6	11/16/1999	12:00	KRUGER	GRAB	SURFACE	377	<.02	<.1	1.00	0.160	0.035	360	2
MC-6	12/08/2000	12:45	SMITH/KRUGER	GRAB	SURFACE	373	<.02	<.1	0.65	0.142	0.032	30	5
MC-6	03/06/2000	10:00	KRUGER	GRAB	SURFACE	259	0.01	0.05	0.80	0.162	0.040	5	1
MC-6	03/08/2000	9:15	KRUGER	GRAB	SURFACE	295	0.01	0.05	1.55	0.212	0.065	5	4
MC-6	04/27/2000		KRUGER	GRAB	SURFACE	403	0.02	0.1	2.30	0.446	0.066	590	40
MC-7	06/08/1999	18:30	KRUGER	GRAB	SURFACE	311	0.12	0.3	2.16	0.334	0.137		
MC-7	06/14/1999	14:10	NIELSEN/KRUGER	GRAB	SURFACE	299	0.14	0.2	1.80	0.184	0.107	100	
MC-7	06/29/1999	14:45	NIELSEN/KRUGER	GRAB	SURFACE	305	<.02	.2	1.64	.172	.117	560	
MC-7	05/11/2000		NIELSEN/KRUGER	GRAB	SURFACE	333	0.32	0.1	1.77	0.241	0.160	60	1

Appendix G. Inlake Sampling Data

SITE	DATE	SAMPLER	TYPE	Depth	Water Temp	Air Temp	Secchi	Dissolved Oxygen	Conductivity	Turbidity	Field pH	Total Solids	Total Dissolved Solids	Total Suspended Solids
CL-1	06/22/1999	Nielsen/ Kruger	Grab	SURFACE	22.00		0.5	10.80			8.38	1308	1250	23
CL-1	07/07/1999	Nielsen/ Kruger	Grab	SURFACE	24.84		0.9	9.10		41.0	8.44	1315	1267	9
CL-1	08/26/1999	Nielsen/ Kruger	Grab	SURFACE	22.75	80	0.7	6.43	1817	118.0	8.22	1442	1347	31
CL-1	09/29/1999	Kruger	Grab	SURFACE	14.12	50	0.5	12.20	1696	41.0	8.80	1427	1352	20
CL-1	10/26/1999	Kruger	Grab	SURFACE	7.95	60	3.0	11.40	1484	5.6	8.48	1425	1391	3
CL-1	02/01/2000	Kruger	Grab	SURFACE	3.55	25	3.0		1545	1.6	8.29	1686	1623	1
CL-2	06/22/1999	Nielsen/ Kruger	Grab	SURFACE	22.00		0.3	11.10			8.42	1351	1221	54
CL-2	07/07/1999	Nielsen/ Kruger	Grab	SURFACE	24.83		1.0	8.22		42.0	8.54	1315	1269	10
CL-2	08/26/1999	Nielsen/ Kruger	Grab	SURFACE	23.44	85	0.6	7.05	1853	128.0	8.48	1440	1350	26
CL-2	09/29/1999	Kruger	Grab	SURFACE	13.66	50	0.7	10.96	1681	108.0	8.88	1411	1353	14
CL-2	10/26/1999	Kruger	Grab	SURFACE	8.05	60	3.0	11.88	1488	5.7	8.61	1436	1398	8
CL-2	02/01/2000	Kruger	Grab	SURFACE	3.99	25	3.0		1553	53.9	8.16	1678	1623	2
CL-3	06/22/1999	Nielsen/ Kruger	Grab	SURFACE	22.50		0.4	10.60			8.40	1356	1227	67
CL-3	07/07/1999	Nielsen/ Kruger	Grab	SURFACE	24.91		1.0	8.87		53.0	8.60	1312	1263	7
CL-3	08/26/1999	Nielsen/ Kruger	Grab	SURFACE	23.90	88	0.3	8.36	1858	84.0	8.65	1455	1352	31
CL-3	09/29/1999	Kruger	Grab	SURFACE	13.72	50	0.9	10.92	1661	40.0	8.93	1414	1353	13
CL-3	10/26/1999	Kruger	Grab	SURFACE	7.81	60	3.0	11.18	1479	31.5	8.73	1446	1390	13
CL-3	02/01/2000	Kruger	Grab	SURFACE	3.70	25	3.0		1549	1.0	8.46	1688	1625	1
CL-1	02/16/2000	Kruger	Grab	SURFACE	4.97	10	3.0	28.61	1571	19.8	8.60	1565	1517	1
CL-2	02/16/2000	Kruger	Grab	SURFACE	2.51	10	3.0	23.58	1451	1.7	8.54	1633	1577	0.50
CL-3	02/16/2000	Kruger	Grab	SURFACE	4.78	10	3.0	28.10	1564	12.9	8.63	1631	1568	2
CL-1	03/23/2000	Kruger	Grab	SURFACE	5.78	45	0.7	11.82		97.7	8.59	1443	1376	19
CL-2	03/23/2000	Kruger	Grab	SURFACE	5.88	45	0.5	12.36		109.5	8.58	1456	1382	20
CL-3	03/23/2000	Kruger	Grab	SURFACE	6.88	45	0.4	12.57		168.9	8.59	1462	1374	32
CL-1	05/01/2000	Kruger	Grab	SURFACE	13.00		0.5	9.05	2047	39.3	8.46	1497	1425	6
CL-2	05/01/2000	Kruger	Grab	SURFACE	13.02		0.6	8.97	2045	47.3	8.48	1501	1427	10
CL-3	05/01/2000	Kruger	Grab	SURFACE	12.97		0.5	9.03	2035	65.4	8.50	1496	1136	10

SITE	DATE	SAMPLER	TYPE	Depth	Total Alkalinity	Ammonia	Nitrate	TKN	Total Phosphorus	Total Dissolved Phosphorus	Fecal Coliforms	Total Volatile Suspended Solids	Chloraphyll A
CL-1	06/22/1999	Nielsen/ Kruger	Grab	SURFACE	304	0.10	0.30	1.85	0.150	0.106	5		5.7
CL-1	07/07/1999	Nielsen/ Kruger	Grab	SURFACE	307	0.01	0.20	1.42	0.209	0.162	5	5.0	24.79
CL-1	08/26/1999	Nielsen/ Kruger	Grab	SURFACE	317	.19	0.05	1.72	0.280	0.188	5	3.0	
CL-1	09/29/1999	Kruger	Grab	SURFACE	314	0.01	0.05	3.42	0.098	0.044	5	8.0	113.23
CL-1	10/26/1999	Kruger	Grab	SURFACE	319	0.02	0.10	1.75	0.206	0.173	10	1.0	3.99
CL-1	02/01/2000	Kruger	Grab	SURFACE	350	0.01	0.10	1.63	0.223	0.189	1	0.5	0.7
CL-2	06/22/1999	Nielsen/ Kruger	Grab	SURFACE	311	0.01	0.30	1.64	0.227	0.113	5		33.17
CL-2	07/07/1999	Nielsen/ Kruger	Grab	SURFACE	305	0.01	0.20	1.60	0.212	0.173	5	5.0	21.11
CL-2	08/26/1999	Nielsen/ Kruger	Grab	SURFACE	317	.12	0.05	1.74	0.261	0.181	5	6.0	
CL-2	09/29/1999	Kruger	Grab	SURFACE	313	0.01	0.05	2.05	0.070	0.049	10	1.0	53.6
CL-2	10/26/1999	Kruger	Grab	SURFACE	319	0.01	0.10	2.62	0.275	0.181	5	6.0	64.99
CL-2	02/01/2000	Kruger	Grab	SURFACE	354	0.01	0.20	1.66	0.241	0.223	1	0.5	0.4
CL-3	06/22/1999	Nielsen/ Kruger	Grab	SURFACE	316	0.09	0.30	1.73	0.237	0.100	10		8.93
CL-3	07/07/1999	Nielsen/ Kruger	Grab	SURFACE	306	0.01	0.20	1.56	0.205	0.149	5	4.0	21.11
CL-3	08/26/1999	Nielsen/ Kruger	Grab	SURFACE	321	.36	0.05	2.77	0.342	0.172	20	10.0	271.02
CL-3	09/29/1999	Kruger	Grab	SURFACE	315	0.01	0.05	1.92	0.070	0.051	5	4.0	114.57
CL-3	10/26/1999	Kruger	Grab	SURFACE	321	0.01	0.10	2.33	0.269	0.181	5	10.0	56.48
CL-3	02/01/2000	Kruger	Grab	SURFACE	349	0.01	0.10	1.61	0.203	0.210	1	0.5	4.46
CL-1	02/16/2000	Kruger	Grab	SURFACE	325	0.01	0.10	1.42	0.218	0.182	1	1.0	0.9
CL-2	02/16/2000	Kruger	Grab	SURFACE	341	0.01	0.05	1.53	0.239	0.218	1	0.5	0.7
CL-3	02/16/2000	Kruger	Grab	SURFACE	335	0.01	0.05	1.48	0.226	0.218	1	0.5	0.44
CL-1	03/23/2000	Kruger	Grab	SURFACE	310	0.03	0.10	1.91	0.282	0.199	5	4.0	3.9
CL-2	03/23/2000	Kruger	Grab	SURFACE	316	0.02	0.05	1.93	0.283	0.201	5	4.0	11.01
CL-3	03/23/2000	Kruger	Grab	SURFACE	315	0.01	0.05	1.91	0.314	0.185	5	6.0	6.41
CL-1	05/01/2000	Kruger	Grab	SURFACE	328	0.15	0.10	1.83	0.242	0.203	5	0.5	
CL-2	05/01/2000	Kruger	Grab	SURFACE	328	0.18	0.10	2.08	0.244	0.196	10	0.5	
CL-3	05/01/2000	Kruger	Grab	SURFACE	325	0.19	0.10	1.98	0.243	0.205	5	0.5	

Appendix H. Algae Metrics and Tables

Lake	LakeID	Date	Shannon10	SpeciesCount	Shannon2	TotalCount	Evenness	EquallyAbund10	PerCyanobacteria	PerAAM	SimpsonDiver
Cottonwood Lake	5702	04/24/1974	0.87	34	2.90	1122	0.57	7.48	68.00%	0.09%	
Cottonwood Lake	5702	07/11/1974	0.46	21	1.54	3757	0.35	2.91	98.56%	76.20%	
Cottonwood Lake	5702	09/18/1974	0.19	12	0.65	14475	0.18	1.57	98.09%	95.88%	
Cottonwood Lake	5702	06/25/1979	0.00	1	0.00	8	0.00	1.00	0.00%	0.00%	
Cottonwood Lake	5702	08/15/1979	0.01	4	0.02	18981	0.01	1.02	99.94%	99.94%	
Cottonwood Lake	5702	07/20/1989	0.14	5	0.47	236756	0.20	1.38	99.98%	9.66%	
Cottonwood Lake	5702	09/07/1989	0.67	12	2.23	2290	0.62	4.70	41.97%	39.30%	
Cottonwood Lake	5702	06/22/1999	0.90	29	2.98	5727	0.61	7.88	81.30%	81.30%	
Cottonwood Lake	5702	07/07/1999	0.81	10	2.68	17157	0.81	6.41	90.76%	90.76%	
Cottonwood Lake	5702	08/26/1999	0.36	9	1.19	40673	0.38	2.29	97.89%	97.89%	
Cottonwood Lake	5702	09/29/1999	0.44	6	1.46	34862	0.56	2.74	97.26%	97.26%	
Cottonwood Lake	5702	10/26/1999	0.55	6	1.83	11971	0.71	3.56	92.05%	92.05%	
Cottonwood Lake	5702	02/01/2000	1.05	11	3.50	1461	1.01	11.29	0.00%	0.00%	
Cottonwood Lake	5702	02/16/2000	1.13	12	3.77	2581	1.05	13.60	0.00%	0.00%	
Cottonwood Lake	5702	03/23/2000	1.10	42	3.65	40168	0.68	12.51	0.10%	0.00%	

Lake	LakeID	Date	SimpsonEvenness	PerDiatoms	SimpsonDominance	PerPennateDiatoms	TSI_B	PerCentricDiatoms	PerGreenAlgae	N2FixerIndex	PerColonialGr
Cottonwood Lake	5702	04/24/1974	0.11	115.42%	0.90	50.89%	52.08	64.53%	0.36%	41.00	
Cottonwood Lake	5702	07/11/1974	0.50	0.24%	0.52	0.13%	43.25	0.11%	4.98%	0.01	
Cottonwood Lake	5702	09/18/1974	0.21	0.01%	0.81	0.00%	53.33	0.01%	0.84%	0.00	
Cottonwood Lake	5702	06/25/1979	0.00	100.00%	1.00	0.00%	31.70	100.00%	0.00%	0.00	
Cottonwood Lake	5702	08/15/1979	0.01	0.04%	1.00	0.00%	55.80	0.04%	0.03%	0.00	
Cottonwood Lake	5702	07/20/1989	0.22	0.00%	0.83	0.00%	71.77	0.00%	0.02%	0.00	
Cottonwood Lake	5702	09/07/1989	0.74	40.74%	0.32	0.00%	66.01	40.74%	10.61%	0.00	
Cottonwood Lake	5702	06/22/1999	0.67	16.68%	0.35	4.02%	49.86	12.66%	6.41%	0.00	
Cottonwood Lake	5702	07/07/1999	0.84	0.06%	0.24	0.00%	50.84	0.06%	3.63%	0.00	
Cottonwood Lake	5702	08/26/1999	0.47	0.41%	0.58	0.13%	61.07	0.28%	0.12%	0.00	
Cottonwood Lake	5702	09/29/1999	0.63	0.23%	0.48	0.23%	59.87	0.00%	0.26%	0.00	
Cottonwood Lake	5702	10/26/1999	0.75	0.00%	0.38	0.00%	51.98	0.00%	3.09%	0.00	
Cottonwood Lake	5702	02/01/2000	0.89	1.37%	0.19	0.82%	32.40	0.55%	4.45%	0.00	
Cottonwood Lake	5702	02/16/2000	0.95	5.42%	0.13	5.11%	36.17	0.31%	3.60%	0.00	
Cottonwood Lake	5702	03/23/2000	0.87	65.84%	0.15	2.92%	63.24	62.92%	7.50%	0.00	

Lake	LakeID	Date	PerChrysophytes	GoodIndicatorSpecies	PerEuglenophytes	AndrewIndex	PerDinoflagellates	PalmerIndex
Cottonwood Lake	5702	04/24/1974	0.00%	NP	10.78%	0.00	0.00%	28.00
Cottonwood Lake	5702	07/11/1974	0.00%	NP	0.00%	0.00	0.00%	3.00
Cottonwood Lake	5702	09/18/1974	0.00%	NP	0.00%	0.00	0.00%	2.00
Cottonwood Lake	5702	06/25/1979	0.00%	NP	0.00%	0.00	0.00%	0.00
Cottonwood Lake	5702	08/15/1979	0.00%	NP	0.00%	0.00	0.00%	2.00
Cottonwood Lake	5702	07/20/1989	0.00%	NP	0.00%	0.00	0.00%	0.00
Cottonwood Lake	5702	09/07/1989	0.00%	NP	0.66%	0.00	0.00%	3.00
Cottonwood Lake	5702	06/22/1999	0.00%	NP	0.00%	0.00	0.00%	13.00
Cottonwood Lake	5702	07/07/1999	0.00%	NP	0.00%	0.00	0.00%	7.00
Cottonwood Lake	5702	08/26/1999	0.00%	NP	0.00%	0.00	0.00%	10.00
Cottonwood Lake	5702	09/29/1999	0.00%	NP	0.00%	0.00	0.00%	5.00
Cottonwood Lake	5702	10/26/1999	0.00%	NP	0.00%	0.00	0.00%	6.00
Cottonwood Lake	5702	02/01/2000	15.74%	NP	0.00%	0.00	0.00%	6.00
Cottonwood Lake	5702	02/16/2000	21.35%	NP	0.00%	0.00	0.00%	9.00
Cottonwood Lake	5702	03/23/2000	3.73%	P	0.04%	1.00	0.01%	31.00

Cottonwood Lake Biovolume Table																
	22-June-99		**22-June-99**		**07-July-99**		**07-July-99**		**26-Aug-99**		**26-Aug-99**		29-Sep-99		29-Sep-99	
	CL-1		**CL-1**		**CL-1**		**CL-1**		**CL-1**		**CL-1**		**CL-1**		**CL-1**	
	Density	**PCT**	Bio Vol	PCT	**Density**	**PCT**	Bio Vol	PCT	**Density**	**PCT**	Bio Vol	PCT	Density	PCT	Bio Vol	PCT
Amphora perpusilla	11	0.8	1777	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Amphora ovalis	14	4.6	8249	5.3	0	0	0	0	0	0	0	0	0	0	0	0
Ankistrodesmus falcatus	64	13.7	1606	0.7	79	1.8	1971	0.2	12	0.7	310	0	40	0.2	1007	0
Aphanizomenon flos-aqua	0	0	0	0	2050	47.9	1230000	95.4	1611	90.3	966429	98.8	22550	98.6	13529997	99.7
Chlamydomonas sp.	0	0	0	0	20	0.5	6406	0.5	0	0	0	0	0	0	0	0
Cryptomonas erosa	18	2.3	9277	0.8	59	1.4	30750	2.4	0	0	0	0	0	0	0	0
Cyclotella meneghiniana	39	8.4	14914	6.2	0	0	0	0	12	0.7	4708	0.5	0	0	0	0
Epithemia turgida	4	0.8	15164	0.7	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema olivaceum	4	0.8	803	0.9	0	0	0	0	0	0	0	0	0	0	0	0
Melosira granulata	21	3.1	11775	3.7	0	0	0	0	0	0	0	0	0	0	0	0
Microcystis aeruginosa	0	0	0	0	1774	6.5	14192	0.4	0	0	0	0	0	0	0	0
Navicula capitata	18	2.3	8563	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Navicula graciloides	4	12.2	1552	0.9	0	0	0	0	0	0	0	0	0	0	0	0
Navicula gregaria	11	0.8	1873	6.8	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia acicularis	0	0	0	0	0	0	0	0	0	0	0	0	40	0.2	11275	0.1
Nitzschia hungarica	4	6.1	1891	4.0	0	0	0	0	0	0	0	0	40	0.2	21342	0.2
Nitzschia tryblionella	4	0.8	678	0.4	0	0	0	0	0	0	0	0	0	0	0	0
Oocystis lacustris	29	3.8	8792	3.9	0	0	0	0	0	0	0	0	0	0	0	0
Oocystis pusilla	29	3.8	1541	4.2	0	0	0	0	0	0	0	0	0	0	0	0
Rhodomonas minuta	57	12.2	1142	0.5	276	41.5	5519	1.1	112	6.3	2230	0.2	201	0.9	4027	0
Sphaerocystis schroeteri	57	8.4	1998	6.7	0	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus astraea	14	6.1	114777	0.7	0	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus astraea minutula	39	5.3	13737	0.2	0	0	0	0	12	0.7	4337	0.4	0	0	0	0
Surirella ovata	4	0.8	1035	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified flagellate	25	3.1	500	51.8	20	0.5	394	0	25	1.4	496	0.1	0	0	0	0
Total Density cells/ml	**467**				**4277**				**1784**				**22872**			
Total Biovolume µm/ml	**221643**				**1289233**				**978509**				**1.356765E+07**			
Trophic State index	**39**				**51.7**				**49.7**				**68.7**			
Diversity index	**3.73**				**1.35**				**0.74**				**0.17**			

Cottonwood Lake Table continued

	26-Oct-99		26-Oct-99		22-June-99		22-June-99		07-July-99		07-July-99		26-Aug-99		26-Aug-99	
	CL-1		CL-1		CL-2		CL-2		CL-2		CL-2		CL-2		CL-2	
	Density	PCT	Bio Vol	PCT	Density	PCT	Bio Vol	PCT	Density	PCT	Bio Vol	PCT	Density	PCT	Bio Vol	PCT
Amphora ovalis	0	0	0	0	11	0.3	6187	1.2	0	0	0	0	0	0	0	0
Ankistrodesmus falcatus	152	13.5	3798	0.8	29	1.8	714	6.3	172	0.4	4303	0.1	0	0	0	0
Aphanizomenon flos-aqua	756	67.1	453701	96.5	0	0	0	0	2754	3.4	1652519	0.4	8419	95.7	5051200	99.4
Chlamydomonas sp.	0	0	0	0	0	0	0	0	0	0	0	0	38	0.4	12215	0.2
Cryptomonas erosa	17	1.5	8777	1.9	43	88.3	22265	4.4	0	0	0	0	0	0	0	0
Cyclotella meneghiniana	0	0	0	0	71	1.9	27117	4.1	0	0	0	0	0	0	0	0
Cyclotella pseudostelligera	0	0	0	0	4	0.1	232	0.3	0	0	0	0	0	0	0	0
Melosira granulata	0	0	0	0	60	1.3	32969	4.3	0	0	0	0	0	0	0	0
Microcystis aeruginosa	0	0	0	0	2890	2.2	23121	5.2	7402	25.2	59215	95.5	0	0	0	0
Navicula graciloides	0	0	0	0	4	0.1	1552	0.1	0	0	0	0	0	0	0	0
Nitzschia tryblionella	0	0	0	0	4	0.1	678	1.3	0	0	0	0	0	0	0	0
Oocystis lacustris	0	0	0	0	7	0.1	2198	0	0	0	0	0	0	0	0	0
Rhodomonas minuta	203	18.0	4051	0.9	36	0.9	714	0.1	369	67.6	7377	3.4	226	2.6	4510	0.1
Sphaerocystis schroeteri	0	0	0	0	0	0	0	0	197	1.6	6885	0.2	0	0	0	0
Stephanodiscus astraea	0	0	0	0	46	1.1	373024	0.1	0	0	0	0	0	0	0	0
Stephanodiscus astraea minutula	0	0	0	0	61	1.4	21230	71.6	0	0	0	0	38	0.4	13154	0.3
Surirella ovata	0	0	0	0	7	0.2	2069	0.4	0	0	0	0	0	0	0	0
Synedra acus	0	0	0	0	4	0.2	6779	0.4	0	0	0	0	0	0	0	0
Unidentified flagellate	0	0	0	0	0	0	0	0	49	1.8	984	0.4	75	0.9	1503	0
Total Density cells/ml	**1128**				**3275**				**10943**				**8794**			
Total Biovolume µm/ml	**470326**				**520848**				**1731285**				**5082582**			
Trophic State index	**44.4**				**45.1**				**53.8**				**61.6**			
Diversity index	**1.47**				**3.34**				**1.40**				**0.42**			

Cottonwood Lake Table continued																
	29-Sep-99		**29-Sep-99**		**26-Oct-99**		**26-Oct-99**		**22-June-99**		**22-June-99**		07-July-99		07-July-99	
	CL-2		**CL-2**		**CL-2**		**CL-2**		**CL-3**		**CL-3**		**CL-3**		**CL-3**	
	Density	**PCT**	Bio Vol	PCT	**Density**	**PCT**	Bio Vol	PC T	**Density**	**PCT**	Bio Vol	PCT	Densi ty	PC T	Bio Vol	PC T
Amphora ovalis	0	0	0	0	0	0	0	0	26	1.1	14902	2.7	0	0	0	0
Anabaena flos-aquae	0	0	0	0	0	0	0	0	13	0.4	12891	0.7	0	0	0	0
Ankistrodesmus falcatus	0	0	0	0	123	2.5	3064	0.1	73	2.5	1826	5.2	77	2.2	1934	2.0
Aphanizomenon flos-aqua	7673	95.6	4603959	99.8	4461	91.5	2676587	98.5	0	0	0	0	1150	58.4	689765	94.3
Chlamydomonas sp.	0	0	0	0	25	0.5	7966	0.3	0	0	0	0	44	1.7	14370	0.1
Cryptomonas erosa	0	0	0	0	49	1.0	25491	0.9	56	2.1	29047	67.7	22	22.5	11496	0.5
Cyclotella meneghiniana	0	0	0	0	0	0	0	0	90	3.8	34289	5.4	0	0	0	0
Melosira granulata	0	0	0	0	0	0	0	0	48	1.3	26469	0.1	11	0.6	6080	0.8
Microcystis aeruginosa	0	0	0	0	0	0	0	0	1753	4.0	14025	6.1	442	9.0	3537	0.5
Navicula capitata	0	0	0	0	0	0	0	0	21	0.9	10313	1.8	0	0	0	0
Navicula graciloides	0	0	0	0	0	0	0	0	9	0.6	3738	2.3	0	0	0	0
Nitzschia amphibia	0	0	0	0	0	0	0	0	4	0.2	413	0.1	0	0	0	0
Nitzschia capitellata	0	0	0	0	0	0	0	0	4	0.2	1547	0.3	0	0	0	0
Rhodomonas minuta	313	3.9	6264	0.1	196	4.0	3922	0.1	30	77.2	602	2.5	177	3.9	3537	0.3
Selenastrum minutum	0	0	0	0	0	0	0	0	4	0.2	86	0	33	1.1	663	1.6
Stephanodiscus astraea	0	0	0	0	0	0	0	0	47	2.1	380110	4.7	0	0	0	0
Stephanodiscus astraea minutula	0	0	0	0	0	0	0	0	86	3.2	30078	0.3	0	0	0	0
Tetrastrum staurogeniaforme	0	0	0	0	0	0	0	0	4	0.2	928	0.2	0	0	0	0
Unidentified flagellate	39	0.5	783	0	25	0.5	490	0	0	0	0	0	11	0.6	221	0
Total Density cells/ml	**8026**				**4878**				**2270**				**1968**			
Total Biovolume µm/ml	**4611006**				**2717520**				**561262**				**731604**			
Trophic State index	**60.9**				**57.1**				**45.7**				**47.6**			
Diversity index	**0.36**				**0.73**				**3.45**				**1.63**			

Cottonwood Lake Table continued																
	26-Aug-99		**26-Aug-99**		**29-Sep-99**		**29-Sep-99**		**26-Oct-99**		**26-Oct-99**		**26-Oct-99**		**26-Oct-99**	
	CL-3		**CL-3**		**CL-3**		**CL-3**		**CL-3**		**CL-3**		**CL-11**		**CL-11**	
	Density	**PCT**	Bio Vol	PCT	**Density**	**PCT**	Bio Vol	PCT	**Density**	**PCT**	Bio Vol	PCT	Density	PCT	Bio Vol	PCT
Ankistrodesmus falcatus	0	0	0	0	52	1.3	1289	0.1	70	1.2	1762	0.1	86	12.8	2141	0.7
Aphanizomenon flos-aqua	29783	98.4	17869806	99.7	3685	91.1	2211188	99.7	5802	96.9	3481156	99.9	460	69.0	275738	96.1
Cryptomonas erosa	53	0.2	27656	0.2	0	0	0	0	0	0	0	0	7	1.1	3711	1.3
Navicula graciloides	0	0	0	0	0	0	0	0	0	0	0	0	7	1.1	3104	1.1
Nitzschia paleacea	53	0.2	5212	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhodomonas minuta	319	1.1	6382	0	283	7.0	5670	0.3	94	1.6	1879	0.1	107	16.1	2141	0.7
Stephanodiscus astraea minutula	53	0.2	18614	0.1	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified flagellate	0	0	0	0	26	0.6	515	0	23	0.4	470	0	0	0	0	0
Total Density cells/ml	**30262**				**4046**				**5990**				**667**			
Total Biovolume µm/ml	**1.792767E+07**				**2218662**				**3485267**				**286835**			
Trophic State index	**70.7**				**55.6**				**58.8**				**40.9**			
Diversity index	**0.18**				**0.62**				**0.30**				**1.49**			

Appendix I. BATHTUB Calculations

Cottonwood Lake

MODEL OPTIONS:

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  1 CONSERVATIVE SUBSTANCE           0 NOT COMPUTED
  2 PHOSPHORUS BALANCE               1 2ND ORDER, AVAIL P
  3 NITROGEN BALANCE                 5 BACHMAN FLUSHING
  4 CHLOROPHYLL-A                    1 P, N, LIGHT, T
  5 SECCHI DEPTH                     2 VS. COMPOSITE NUTRIENT
  6 DISPERSION                       1 FISCHER-NUMERIC
  7 PHOSPHORUS CALIBRATION           2 CONCENTRATIONS
  8 NITROGEN CALIBRATION             2 CONCENTRATIONS
  9 ERROR ANALYSIS                   1 MODEL & DATA
 10 AVAILABILITY FACTORS             1 USE FOR MODEL 1 ONLY
 11 MASS-BALANCE TABLES              1 USE ESTIMATED CONCS
```

ATMOSPHERIC LOADS & AVAILABILITY FACTORS:

```
             ATMOSPHERIC-LOADS   AVAILABILITY
 VARIABLE     KG/KM2-YR      CV      FACTOR
  1 CONSERV         .00     .00         .00
  2 TOTAL P       28.00     .50        1.33
  3 TOTAL N     1310.00     .50         .59
  4 ORTHO P       10.00     .50         .33
  5 INORG N      700.00     .50         .79
```

GLOBAL INPUT VALUES:

```
 PARAMETER                      MEAN      CV
 PERIOD LENGTH     YRS         1.000    .000
 PRECIPITATION M                .457    .200
 EVAPORATION   M                .889    .300
 INCREASE IN STORAGE M          .000    .000
```

TRIBUTARY DRAINAGE AREAS AND FLOWS:

```
 ID TYPE SEG NAME            DRAINAGE AREA    MEAN FLOW  CV OF MEAN FLOW
                                       KM2       HM3/YR
  1   1    1 Medicine Creek        611.000        9.536        .000
  2   3    1 Groundwater              .000        1.008        .000
 TRIBUTARY CONCENTRATIONS (PPB): MEAN/CV
 ID       CONSERV      TOTAL P      TOTAL N      ORTHO P      INORG N
  1      .0/ .00   618.1/ .13  2406.6/ .03   363.6/ .29    74.8/ .20
  2      .0/ .00  2058.0/ .51  1410.0/ .43     1.6/ .76   570.0/ .00
 MODEL SEGMENTS & CALIBRATION FACTORS:
                                    ----------- CALIBRATION FACTORS -----------
 SEG OUTFLOW GROUP SEGMENT NAME       P SED  N SED  CHL-A SECCHI    HOD      DISP
  1       0     1  Cotton 1            1.00   1.00   1.00   1.00   1.00     1.000
                               CV:     .000   .000   .000   .000   .000      .000
 SEGMENT MORPHOMETRY: MEAN/CV
                     LENGTH      AREA  ZMEAN       ZMIX       ZHYP
 ID LABEL                KM       KM2      M          M          M
  1 Cotton 1           3.10    6.6700   1.98   1.98/ .12    .00/ .00
 SEGMENT OBSERVED WATER QUALITY:
 SEG    TURBID CONSER TOTALP TOTALN  CHL-A SECCHI  ORG-N  TP-OP   HODV   MODV
           1/M   ---   MG/M3  MG/M3  MG/M3      M  MG/M3  MG/M3 MG/M3-D MG/M3-D
  1 MN:   2.40     .0  225.0 2115.0   50.9    1.0 1897.0   77.0     .0     .0
    CV:   2.25    .00    .31    .19   1.35    .93    .23    .55    .00    .00
 MODEL COEFFICIENTS:
 COEFFICIENT            MEAN      CV
 DISPERSION FACTO      1.000     .70
 P DECAY RATE          1.000     .45
 N DECAY RATE          1.000     .55
 CHL-A MODEL           1.000     .26
 SECCHI MODEL          3.000     .10
 ORGANIC N MODEL       1.000     .12
 TP-OP MODEL           1.000     .15
 HODV MODEL            1.000     .15
 MODV MODEL            1.000     .22
 BETA  M2/MG            .025     .00
 MINIMUM QS             .100     .00
 FLUSHING EFFECT       1.000     .00
 CHLOROPHYLL-A CV       .620     .00
```

SEGMENT NETWORK: FLOWS IN HM3/YR

*************** SEGMENT:	1 Cotton 1	INFLOW	OUTFLOW	EXCHANGE
PRECIP AND EVAPORATION:		3.05	5.93	
EXTERNAL INFLOW:	1 Medicine Creek	9.54		
EXTERNAL INFLOW:	2 Groundwater	1.01		
DISCHARGE OUT OF SYSTEM:			7.66	

CASE: Cottonwood Lake

GROSS WATER BALANCE:

ID T LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1 1 Medicine Creek	611.000	9.536	.000E+00	.000	.016
2 3 Groundwater	.000	1.008	.000E+00	.000	.000
PRECIPITATION	6.670	3.048	.372E+00	.200	.457
TRIBUTARY INFLOW	611.000	9.536	.000E+00	.000	.016
POINT-SOURCE INFLOW	.000	1.008	.000E+00	.000	.000
***TOTAL INFLOW	617.670	13.592	.372E+00	.045	.022
ADVECTIVE OUTFLOW	617.670	7.663	.354E+01	.245	.012
***TOTAL OUTFLOW	617.670	7.663	.354E+01	.245	.012
***EVAPORATION	.000	5.930	.316E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID T LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1 1 Medicine Creek	8983.5	74.8	.183E+07	47.8	.151	942.1	14.7
2 3 Groundwater	2759.6	23.0	.198E+07	51.7	.510	2737.7	.0
PRECIPITATION	270.4	2.3	.183E+05	.5	.500	88.7	40.5
TRIBUTARY INFLOW	8983.5	74.8	.183E+07	47.8	.151	942.1	14.7
POINT-SOURCE INFLOW	2759.6	23.0	.198E+07	51.7	.510	2737.7	.0
***TOTAL INFLOW	12013.5	100.0	.383E+07	100.0	.163	883.9	19.4
ADVECTIVE OUTFLOW	1830.2	15.2	.754E+06	19.7	.474	238.8	3.0
***TOTAL OUTFLOW	1830.2	15.2	.754E+06	19.7	.474	238.8	3.0
***RETENTION	10183.3	84.8	.396E+07	103.3	.195	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	-------------- TOTAL P -------------- POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
1.15	1.7235	225.0	.2473	4.0429	.8477

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL N

ID T LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1 1 Medicine Creek	22949.3	69.3	.539E+06	2.7	.032	2406.6	37.6
2 3 Groundwater	1421.3	4.3	.374E+06	1.9	.430	1410.0	.0
PRECIPITATION	8737.7	26.4	.191E+08	95.4	.500	2866.5	1310.0
TRIBUTARY INFLOW	22949.3	69.3	.539E+06	2.7	.032	2406.6	37.6
POINT-SOURCE INFLOW	1421.3	4.3	.374E+06	1.9	.430	1410.0	.0
***TOTAL INFLOW	33108.3	100.0	.200E+08	100.0	.135	2435.8	53.6
ADVECTIVE OUTFLOW	17560.7	53.0	.998E+08	498.8	.569	2291.8	28.4
***TOTAL OUTFLOW	17560.7	53.0	.998E+08	498.8	.569	2291.8	28.4
***RETENTION	15547.6	47.0	.985E+08	492.7	.638	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	-------------- TOTAL N -------------- POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
1.15	1.7235	2115.0	.8437	1.1853	.4696

SEGMENT: Current Conditions

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	238.85	95.7	96.3
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	142.97	94.9	95.9
CHL-A MG/M3	50.88	46.22	98.6	98.1
SECCHI M	.95	.96	43.4	44.0
ORGANIC N MG/M3	1897.00	1391.78	99.7	98.3
TP-ORTHO-P MG/M3	77.00	135.11	83.9	94.3
ANTILOG PC-1	2341.09	2065.28	95.8	94.8
ANTILOG PC-2	18.09	15.98	97.5	95.8
(N - 150) / P	8.73	8.97	16.4	17.4
INORGANIC N / P	1.47	8.68	.1	10.8
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	2.05	7.7	7.4
CHL-A * SECCHI	48.43	44.55	98.6	98.1
CHL-A / TOTAL P	.23	.19	58.9	49.2
FREQ(CHL-a>10) %	98.97	98.46	.0	.0
FREQ(CHL-a>20) %	88.42	85.12	.0	.0
FREQ(CHL-a>30) %	70.61	65.08	.0	.0
FREQ(CHL-a>40) %	53.11	46.93	.0	.0
FREQ(CHL-a>50) %	38.89	33.11	.0	.0
FREQ(CHL-a>60) %	28.23	23.24	.0	.0
CARLSON TSI-P	82.25	83.11	.0	.0
CARLSON TSI-CHLA	69.15	68.21	.0	.0
CARLSON TSI-SEC	60.71	60.53	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 50% reduction in Septic Loads

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	224.01	95.7	95.7
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	139.59	94.9	95.6
CHL-A MG/M3	50.88	45.56	98.6	98.0
SECCHI M	.95	.98	43.4	45.0
ORGANIC N MG/M3	1897.00	1376.52	99.7	98.2
TP-ORTHO-P MG/M3	77.00	133.92	83.9	94.2
ANTILOG PC-1	2341.09	1994.35	95.8	94.5
ANTILOG PC-2	18.09	16.08	97.5	95.9
(N - 150) / P	8.73	9.56	16.4	19.9
INORGANIC N / P	1.47	10.16	.1	14.0
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	2.02	7.7	6.9
CHL-A * SECCHI	48.43	44.74	98.6	98.2
CHL-A / TOTAL P	.23	.20	58.9	52.3
FREQ(CHL-a>10) %	98.97	98.36	.0	.0
FREQ(CHL-a>20) %	88.42	84.56	.0	.0
FREQ(CHL-a>30) %	70.61	64.20	.0	.0
FREQ(CHL-a>40) %	53.11	46.00	.0	.0
FREQ(CHL-a>50) %	38.89	32.27	.0	.0
FREQ(CHL-a>60) %	28.23	22.53	.0	.0
CARLSON TSI-P	82.25	82.19	.0	.0
CARLSON TSI-CHLA	69.15	68.06	.0	.0
CARLSON TSI-SEC	60.71	60.26	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 100% reduction in Septic Loads

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	208.24	95.7	94.9
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	135.51	94.9	95.2
CHL-A MG/M3	50.88	44.72	98.6	97.9
SECCHI M	.95	1.01	43.4	46.2
ORGANIC N MG/M3	1897.00	1357.58	99.7	98.0
TP-ORTHO-P MG/M3	77.00	132.44	83.9	94.1
ANTILOG PC-1	2341.09	1909.37	95.8	94.1
ANTILOG PC-2	18.09	16.19	97.5	96.0
(N - 150) / P	8.73	10.29	16.4	23.0
INORGANIC N / P	1.47	12.32	.1	18.8
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.97	7.7	6.4
CHL-A * SECCHI	48.43	44.97	98.6	98.2
CHL-A / TOTAL P	.23	.21	58.9	55.7
FREQ(CHL-a>10) %	98.97	98.24	.0	.0
FREQ(CHL-a>20) %	88.42	83.85	.0	.0
FREQ(CHL-a>30) %	70.61	63.09	.0	.0
FREQ(CHL-a>40) %	53.11	44.82	.0	.0
FREQ(CHL-a>50) %	38.89	31.21	.0	.0
FREQ(CHL-a>60) %	28.23	21.65	.0	.0
CARLSON TSI-P	82.25	81.13	.0	.0
CARLSON TSI-CHLA	69.15	67.88	.0	.0
CARLSON TSI-SEC	60.71	59.92	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: No Septic/ 10% reduction at Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	197.01	95.7	94.2
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	132.27	94.9	94.9
CHL-A MG/M3	50.88	44.04	98.6	97.8
SECCHI M	.95	1.02	43.4	47.2
ORGANIC N MG/M3	1897.00	1342.06	99.7	97.9
TP-ORTHO-P MG/M3	77.00	131.22	83.9	94.0
ANTILOG PC-1	2341.09	1842.18	95.8	93.8
ANTILOG PC-2	18.09	16.28	97.5	96.1
(N - 150) / P	8.73	10.87	16.4	25.6
INORGANIC N / P	1.47	14.44	.1	23.4
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.93	7.7	6.0
CHL-A * SECCHI	48.43	45.14	98.6	98.2
CHL-A / TOTAL P	.23	.22	58.9	58.2
FREQ(CHL-a>10) %	98.97	98.13	.0	.0
FREQ(CHL-a>20) %	88.42	83.23	.0	.0
FREQ(CHL-a>30) %	70.61	62.15	.0	.0
FREQ(CHL-a>40) %	53.11	43.85	.0	.0
FREQ(CHL-a>50) %	38.89	30.34	.0	.0
FREQ(CHL-a>60) %	28.23	20.93	.0	.0
CARLSON TSI-P	82.25	80.33	.0	.0
CARLSON TSI-CHLA	69.15	67.73	.0	.0
CARLSON TSI-SEC	60.71	59.65	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 100% Septic Reduction/ 20% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	185.17	95.7	93.4
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	128.51	94.9	94.5
CHL-A MG/M3	50.88	43.23	98.6	97.6
SECCHI M	.95	1.05	43.4	48.4
ORGANIC N MG/M3	1897.00	1323.53	99.7	97.8
TP-ORTHO-P MG/M3	77.00	129.78	83.9	93.8
ANTILOG PC-1	2341.09	1764.72	95.8	93.4
ANTILOG PC-2	18.09	16.38	97.5	96.2
(N - 150) / P	8.73	11.57	16.4	28.6
INORGANIC N / P	1.47	17.48	.1	29.7
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.89	7.7	5.6
CHL-A * SECCHI	48.43	45.33	98.6	98.2
CHL-A / TOTAL P	.23	.23	58.9	60.8
FREQ(CHL-a>10) %	98.97	97.99	.0	.0
FREQ(CHL-a>20) %	88.42	82.47	.0	.0
FREQ(CHL-a>30) %	70.61	61.01	.0	.0
FREQ(CHL-a>40) %	53.11	42.66	.0	.0
FREQ(CHL-a>50) %	38.89	29.30	.0	.0
FREQ(CHL-a>60) %	28.23	20.08	.0	.0
CARLSON TSI-P	82.25	79.44	.0	.0
CARLSON TSI-CHLA	69.15	67.55	.0	.0
CARLSON TSI-SEC	60.71	59.32	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 100% Septic/ 30% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	172.62	95.7	92.3
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	124.08	94.9	94.0
CHL-A MG/M3	50.88	42.24	98.6	97.5
SECCHI M	.95	1.08	43.4	49.9
ORGANIC N MG/M3	1897.00	1301.03	99.7	97.6
TP-ORTHO-P MG/M3	77.00	128.02	83.9	93.7
ANTILOG PC-1	2341.09	1674.43	95.8	92.9
ANTILOG PC-2	18.09	16.50	97.5	96.3
(N - 150) / P	8.73	12.41	16.4	32.2
INORGANIC N / P	1.47	22.22	.1	38.5
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.84	7.7	5.1
CHL-A * SECCHI	48.43	45.54	98.6	98.3
CHL-A / TOTAL P	.23	.24	58.9	63.7
FREQ(CHL-a>10) %	98.97	97.80	.0	.0
FREQ(CHL-a>20) %	88.42	81.49	.0	.0
FREQ(CHL-a>30) %	70.61	59.57	.0	.0
FREQ(CHL-a>40) %	53.11	41.21	.0	.0
FREQ(CHL-a>50) %	38.89	28.03	.0	.0
FREQ(CHL-a>60) %	28.23	19.05	.0	.0
CARLSON TSI-P	82.25	78.43	.0	.0
CARLSON TSI-CHLA	69.15	67.32	.0	.0
CARLSON TSI-SEC	60.71	58.92	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 100% Septic/ 40% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	159.19	95.7	90.9
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	118.80	94.9	93.4
CHL-A MG/M3	50.88	41.02	98.6	97.2
SECCHI M	.95	1.12	43.4	51.7
ORGANIC N MG/M3	1897.00	1273.13	99.7	97.4
TP-ORTHO-P MG/M3	77.00	125.84	83.9	93.4
ANTILOG PC-1	2341.09	1567.98	95.8	92.2
ANTILOG PC-2	18.09	16.64	97.5	96.5
(N - 150) / P	8.73	13.45	16.4	36.6
INORGANIC N / P	1.47	30.55	.1	51.1
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.77	7.7	4.5
CHL-A * SECCHI	48.43	45.76	98.6	98.3
CHL-A / TOTAL P	.23	.26	58.9	66.7
FREQ(CHL-a>10) %	98.97	97.54	.0	.0
FREQ(CHL-a>20) %	88.42	80.20	.0	.0
FREQ(CHL-a>30) %	70.61	57.72	.0	.0
FREQ(CHL-a>40) %	53.11	39.38	.0	.0
FREQ(CHL-a>50) %	38.89	26.45	.0	.0
FREQ(CHL-a>60) %	28.23	17.79	.0	.0
CARLSON TSI-P	82.25	77.26	.0	.0
CARLSON TSI-CHLA	69.15	67.03	.0	.0
CARLSON TSI-SEC	60.71	58.42	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 100% Septic/ 50% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	144.68	95.7	89.0
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	112.39	94.9	92.4
CHL-A MG/M3	50.88	39.46	98.6	96.9
SECCHI M	.95	1.17	43.4	54.0
ORGANIC N MG/M3	1897.00	1237.60	99.7	97.0
TP-ORTHO-P MG/M3	77.00	123.07	83.9	93.1
ANTILOG PC-1	2341.09	1440.61	95.8	91.2
ANTILOG PC-2	18.09	16.80	97.5	96.6
(N - 150) / P	8.73	14.80	16.4	41.9
INORGANIC N / P	1.47	48.78	.1	69.1
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.70	7.7	3.8
CHL-A * SECCHI	48.43	46.00	98.6	98.3
CHL-A / TOTAL P	.23	.27	58.9	69.8
FREQ(CHL-a>10) %	98.97	97.16	.0	.0
FREQ(CHL-a>20) %	88.42	78.41	.0	.0
FREQ(CHL-a>30) %	70.61	55.27	.0	.0
FREQ(CHL-a>40) %	53.11	36.99	.0	.0
FREQ(CHL-a>50) %	38.89	24.45	.0	.0
FREQ(CHL-a>60) %	28.23	16.21	.0	.0
CARLSON TSI-P	82.25	75.88	.0	.0
CARLSON TSI-CHLA	69.15	66.66	.0	.0
CARLSON TSI-SEC	60.71	57.79	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 100% Septic/ 60% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	128.75	95.7	86.4
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	104.42	94.9	91.0
CHL-A MG/M3	50.88	37.41	98.6	96.4
SECCHI M	.95	1.24	43.4	57.0
ORGANIC N MG/M3	1897.00	1190.76	99.7	96.5
TP-ORTHO-P MG/M3	77.00	119.41	83.9	92.7
ANTILOG PC-1	2341.09	1285.47	95.8	89.7
ANTILOG PC-2	18.09	16.99	97.5	96.8
(N - 150) / P	8.73	16.64	16.4	48.7
INORGANIC N / P	1.47	117.94	.1	91.7
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.60	7.7	3.0
CHL-A * SECCHI	48.43	46.21	98.6	98.4
CHL-A / TOTAL P	.23	.29	58.9	73.2
FREQ(CHL-a>10) %	98.97	96.55	.0	.0
FREQ(CHL-a>20) %	88.42	75.80	.0	.0
FREQ(CHL-a>30) %	70.61	51.84	.0	.0
FREQ(CHL-a>40) %	53.11	33.79	.0	.0
FREQ(CHL-a>50) %	38.89	21.83	.0	.0
FREQ(CHL-a>60) %	28.23	14.18	.0	.0
CARLSON TSI-P	82.25	74.20	.0	.0
CARLSON TSI-CHLA	69.15	66.13	.0	.0
CARLSON TSI-SEC	60.71	56.95	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 100% septic/ 70% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	110.95	95.7	82.5
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	94.23	94.9	88.7
CHL-A MG/M3	50.88	34.58	98.6	95.5
SECCHI M	.95	1.34	43.4	61.2
ORGANIC N MG/M3	1897.00	1126.33	99.7	95.5
TP-ORTHO-P MG/M3	77.00	114.38	83.9	92.1
ANTILOG PC-1	2341.09	1093.44	95.8	87.3
ANTILOG PC-2	18.09	17.21	97.5	96.9
(N - 150) / P	8.73	19.30	16.4	57.4
INORGANIC N / P	1.47	1165.42	.1	100.0
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.48	7.7	2.2
CHL-A * SECCHI	48.43	46.33	98.6	98.4
CHL-A / TOTAL P	.23	.31	58.9	76.7
FREQ(CHL-a>10) %	98.97	95.46	.0	.0
FREQ(CHL-a>20) %	88.42	71.68	.0	.0
FREQ(CHL-a>30) %	70.61	46.77	.0	.0
FREQ(CHL-a>40) %	53.11	29.29	.0	.0
FREQ(CHL-a>50) %	38.89	18.28	.0	.0
FREQ(CHL-a>60) %	28.23	11.53	.0	.0
CARLSON TSI-P	82.25	72.05	.0	.0
CARLSON TSI-CHLA	69.15	65.36	.0	.0
CARLSON TSI-SEC	60.71	55.78	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 100% Septic/ 80% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	90.34	95.7	76.0
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	80.60	94.9	84.6
CHL-A MG/M3	50.88	30.43	98.6	93.7
SECCHI M	.95	1.52	43.4	67.2
ORGANIC N MG/M3	1897.00	1031.58	99.7	93.6
TP-ORTHO-P MG/M3	77.00	106.99	83.9	91.0
ANTILOG PC-1	2341.09	849.87	95.8	82.9
ANTILOG PC-2	18.09	17.44	97.5	97.1
(N - 150) / P	8.73	23.71	16.4	68.7
INORGANIC N / P	1.47	1260.17	.1	100.0
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.31	7.7	1.3
CHL-A * SECCHI	48.43	46.12	98.6	98.3
CHL-A / TOTAL P	.23	.34	58.9	80.3
FREQ(CHL-a>10) %	98.97	93.12	.0	.0
FREQ(CHL-a>20) %	88.42	64.31	.0	.0
FREQ(CHL-a>30) %	70.61	38.69	.0	.0
FREQ(CHL-a>40) %	53.11	22.62	.0	.0
FREQ(CHL-a>50) %	38.89	13.32	.0	.0
FREQ(CHL-a>60) %	28.23	8.00	.0	.0
CARLSON TSI-P	82.25	69.09	.0	.0
CARLSON TSI-CHLA	69.15	64.10	.0	.0
CARLSON TSI-SEC	60.71	54.01	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 100% Septic/ 90% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	64.96	95.7	63.3
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	61.04	94.9	74.9
CHL-A MG/M3	50.88	23.45	98.6	88.3
SECCHI M	.95	1.89	43.4	76.9
ORGANIC N MG/M3	1897.00	872.52	99.7	88.4
TP-ORTHO-P MG/M3	77.00	94.57	83.9	88.7
ANTILOG PC-1	2341.09	530.90	95.8	72.3
ANTILOG PC-2	18.09	17.42	97.5	97.1
(N - 150) / P	8.73	32.97	16.4	83.5
INORGANIC N / P	1.47	1419.23	.1	100.0
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.05	7.7	.5
CHL-A * SECCHI	48.43	44.27	98.6	98.1
CHL-A / TOTAL P	.23	.36	58.9	83.2
FREQ(CHL-a>10) %	98.97	85.65	.0	.0
FREQ(CHL-a>20) %	88.42	47.86	.0	.0
FREQ(CHL-a>30) %	70.61	23.97	.0	.0
FREQ(CHL-a>40) %	53.11	12.07	.0	.0
FREQ(CHL-a>50) %	38.89	6.28	.0	.0
FREQ(CHL-a>60) %	28.23	3.40	.0	.0
CARLSON TSI-P	82.25	64.34	.0	.0
CARLSON TSI-CHLA	69.15	61.55	.0	.0
CARLSON TSI-SEC	60.71	50.84	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 50% Septic/ 10% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	213.54	95.7	95.2
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	136.94	94.9	95.4
CHL-A MG/M3	50.88	45.02	98.6	97.9
SECCHI M	.95	1.00	43.4	45.8
ORGANIC N MG/M3	1897.00	1364.29	99.7	98.1
TP-ORTHO-P MG/M3	77.00	132.96	83.9	94.1
ANTILOG PC-1	2341.09	1939.09	95.8	94.3
ANTILOG PC-2	18.09	16.15	97.5	96.0
(N - 150) / P	8.73	10.03	16.4	21.9
INORGANIC N / P	1.47	11.51	.1	17.0
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.99	7.7	6.6
CHL-A * SECCHI	48.43	44.89	98.6	98.2
CHL-A / TOTAL P	.23	.21	58.9	54.6
FREQ(CHL-a>10) %	98.97	98.28	.0	.0
FREQ(CHL-a>20) %	88.42	84.10	.0	.0
FREQ(CHL-a>30) %	70.61	63.49	.0	.0
FREQ(CHL-a>40) %	53.11	45.24	.0	.0
FREQ(CHL-a>50) %	38.89	31.58	.0	.0
FREQ(CHL-a>60) %	28.23	21.96	.0	.0
CARLSON TSI-P	82.25	81.50	.0	.0
CARLSON TSI-CHLA	69.15	67.95	.0	.0
CARLSON TSI-SEC	60.71	60.04	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 50% Septic/ 20% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	202.58	95.7	94.5
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	133.92	94.9	95.1
CHL-A MG/M3	50.88	44.39	98.6	97.8
SECCHI M	.95	1.01	43.4	46.7
ORGANIC N MG/M3	1897.00	1349.99	99.7	98.0
TP-ORTHO-P MG/M3	77.00	131.84	83.9	94.0
ANTILOG PC-1	2341.09	1876.24	95.8	94.0
ANTILOG PC-2	18.09	16.23	97.5	96.1
(N - 150) / P	8.73	10.57	16.4	24.3
INORGANIC N / P	1.47	13.31	.1	21.0
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.95	7.7	6.2
CHL-A * SECCHI	48.43	45.05	98.6	98.2
CHL-A / TOTAL P	.23	.22	58.9	57.0
FREQ(CHL-a>10) %	98.97	98.19	.0	.0
FREQ(CHL-a>20) %	88.42	83.55	.0	.0
FREQ(CHL-a>30) %	70.61	62.63	.0	.0
FREQ(CHL-a>40) %	53.11	44.35	.0	.0
FREQ(CHL-a>50) %	38.89	30.78	.0	.0
FREQ(CHL-a>60) %	28.23	21.30	.0	.0
CARLSON TSI-P	82.25	80.74	.0	.0
CARLSON TSI-CHLA	69.15	67.81	.0	.0
CARLSON TSI-SEC	60.71	59.79	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 50% septic Reductions/ 30% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	191.05	95.7	93.8
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	130.42	94.9	94.7
CHL-A MG/M3	50.88	43.65	98.6	97.7
SECCHI M	.95	1.04	43.4	47.8
ORGANIC N MG/M3	1897.00	1333.03	99.7	97.9
TP-ORTHO-P MG/M3	77.00	130.52	83.9	93.9
ANTILOG PC-1	2341.09	1804.06	95.8	93.6
ANTILOG PC-2	18.09	16.33	97.5	96.2
(N - 150) / P	8.73	11.21	16.4	27.0
INORGANIC N / P	1.47	15.84	.1	26.4
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.91	7.7	5.8
CHL-A * SECCHI	48.43	45.23	98.6	98.2
CHL-A / TOTAL P	.23	.23	58.9	59.5
FREQ(CHL-a>10) %	98.97	98.06	.0	.0
FREQ(CHL-a>20) %	88.42	82.87	.0	.0
FREQ(CHL-a>30) %	70.61	61.60	.0	.0
FREQ(CHL-a>40) %	53.11	43.27	.0	.0
FREQ(CHL-a>50) %	38.89	29.83	.0	.0
FREQ(CHL-a>60) %	28.23	20.52	.0	.0
CARLSON TSI-P	82.25	79.89	.0	.0
CARLSON TSI-CHLA	69.15	67.64	.0	.0
CARLSON TSI-SEC	60.71	59.49	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 50 % Septic/ 40% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	178.86	95.7	92.8
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	126.34	94.9	94.3
CHL-A MG/M3	50.88	42.75	98.6	97.6
SECCHI M	.95	1.06	43.4	49.1
ORGANIC N MG/M3	1897.00	1312.62	99.7	97.7
TP-ORTHO-P MG/M3	77.00	128.93	83.9	93.8
ANTILOG PC-1	2341.09	1720.44	95.8	93.2
ANTILOG PC-2	18.09	16.44	97.5	96.3
(N - 150) / P	8.73	11.97	16.4	30.3
INORGANIC N / P	1.47	19.61	.1	33.8
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.86	7.7	5.3
CHL-A * SECCHI	48.43	45.43	98.6	98.3
CHL-A / TOTAL P	.23	.24	58.9	62.3
FREQ(CHL-a>10) %	98.97	97.90	.0	.0
FREQ(CHL-a>20) %	88.42	82.00	.0	.0
FREQ(CHL-a>30) %	70.61	60.31	.0	.0
FREQ(CHL-a>40) %	53.11	41.96	.0	.0
FREQ(CHL-a>50) %	38.89	28.68	.0	.0
FREQ(CHL-a>60) %	28.23	19.58	.0	.0
CARLSON TSI-P	82.25	78.94	.0	.0
CARLSON TSI-CHLA	69.15	67.44	.0	.0
CARLSON TSI-SEC	60.71	59.12	.0	.0

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 50% septic/ 50% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	165.88	95.7	91.6
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	121.51	94.9	93.7
CHL-A MG/M3	50.88	41.65	98.6	97.3
SECCHI M	.95	1.10	43.4	50.8
ORGANIC N MG/M3	1897.00	1287.58	99.7	97.5
TP-ORTHO-P MG/M3	77.00	126.97	83.9	93.6
ANTILOG PC-1	2341.09	1622.37	95.8	92.6
ANTILOG PC-2	18.09	16.57	97.5	96.4
(N - 150) / P	8.73	12.91	16.4	34.3
INORGANIC N / P	1.47	25.81	.1	44.4
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.81	7.7	4.8
CHL-A * SECCHI	48.43	45.65	98.6	98.3
CHL-A / TOTAL P	.23	.25	58.9	65.2
FREQ(CHL-a>10) %	98.97	97.68	.0	.0
FREQ(CHL-a>20) %	88.42	80.88	.0	.0
FREQ(CHL-a>30) %	70.61	58.69	.0	.0
FREQ(CHL-a>40) %	53.11	40.33	.0	.0
FREQ(CHL-a>50) %	38.89	27.27	.0	.0
FREQ(CHL-a>60) %	28.23	18.44	.0	.0
CARLSON TSI-P	82.25	77.85	.0	.0
CARLSON TSI-CHLA	69.15	67.19	.0	.0
CARLSON TSI-SEC	60.71	58.68	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 50% Septic/ 60% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	151.91	95.7	90.0
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	115.68	94.9	92.9
CHL-A MG/M3	50.88	40.27	98.6	97.1
SECCHI M	.95	1.14	43.4	52.8
ORGANIC N MG/M3	1897.00	1256.07	99.7	97.2
TP-ORTHO-P MG/M3	77.00	124.51	83.9	93.3
ANTILOG PC-1	2341.09	1505.73	95.8	91.7
ANTILOG PC-2	18.09	16.72	97.5	96.5
(N - 150) / P	8.73	14.10	16.4	39.2
INORGANIC N / P	1.47	37.80	.1	59.6
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.74	7.7	4.1
CHL-A * SECCHI	48.43	45.88	98.6	98.3
CHL-A / TOTAL P	.23	.27	58.9	68.3
FREQ(CHL-a>10) %	98.97	97.36	.0	.0
FREQ(CHL-a>20) %	88.42	79.36	.0	.0
FREQ(CHL-a>30) %	70.61	56.56	.0	.0
FREQ(CHL-a>40) %	53.11	38.24	.0	.0
FREQ(CHL-a>50) %	38.89	25.49	.0	.0
FREQ(CHL-a>60) %	28.23	17.03	.0	.0
CARLSON TSI-P	82.25	76.59	.0	.0
CARLSON TSI-CHLA	69.15	66.85	.0	.0
CARLSON TSI-SEC	60.71	58.12	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 50% septic/ 70% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	136.74	95.7	87.8
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	108.54	94.9	91.8
CHL-A MG/M3	50.88	38.49	98.6	96.7
SECCHI M	.95	1.20	43.4	55.4
ORGANIC N MG/M3	1897.00	1215.39	99.7	96.8
TP-ORTHO-P MG/M3	77.00	121.34	83.9	92.9
ANTILOG PC-1	2341.09	1365.31	95.8	90.5
ANTILOG PC-2	18.09	16.90	97.5	96.7
(N - 150) / P	8.73	15.66	16.4	45.2
INORGANIC N / P	1.47	69.88	.1	80.5
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.65	7.7	3.4
CHL-A * SECCHI	48.43	46.11	98.6	98.3
CHL-A / TOTAL P	.23	.28	58.9	71.5
FREQ(CHL-a>10) %	98.97	96.88	.0	.0
FREQ(CHL-a>20) %	88.42	77.21	.0	.0
FREQ(CHL-a>30) %	70.61	53.67	.0	.0
FREQ(CHL-a>40) %	53.11	35.48	.0	.0
FREQ(CHL-a>50) %	38.89	23.20	.0	.0
FREQ(CHL-a>60) %	28.23	15.24	.0	.0
CARLSON TSI-P	82.25	75.07	.0	.0
CARLSON TSI-CHLA	69.15	66.41	.0	.0
CARLSON TSI-SEC	60.71	57.40	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 50% septic/ 80% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	119.94	95.7	84.6
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	99.55	94.9	90.0
CHL-A MG/M3	50.88	36.09	98.6	96.0
SECCHI M	.95	1.28	43.4	59.0
ORGANIC N MG/M3	1897.00	1160.66	99.7	96.0
TP-ORTHO-P MG/M3	77.00	117.06	83.9	92.4
ANTILOG PC-1	2341.09	1192.85	95.8	88.7
ANTILOG PC-2	18.09	17.10	97.5	96.9
(N - 150) / P	8.73	17.86	16.4	52.9
INORGANIC N / P	1.47	392.92	.1	99.5
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.54	7.7	2.6
CHL-A * SECCHI	48.43	46.30	98.6	98.4
CHL-A / TOTAL P	.23	.30	58.9	75.0
FREQ(CHL-a>10) %	98.97	96.08	.0	.0
FREQ(CHL-a>20) %	88.42	73.96	.0	.0
FREQ(CHL-a>30) %	70.61	49.51	.0	.0
FREQ(CHL-a>40) %	53.11	31.70	.0	.0
FREQ(CHL-a>50) %	38.89	20.16	.0	.0
FREQ(CHL-a>60) %	28.23	12.92	.0	.0
CARLSON TSI-P	82.25	73.18	.0	.0
CARLSON TSI-CHLA	69.15	65.78	.0	.0
CARLSON TSI-SEC	60.71	56.41	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 50% Septic / 90% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	100.87	95.7	79.6
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	87.81	94.9	87.0
CHL-A MG/M3	50.88	32.68	98.6	94.7
SECCHI M	.95	1.42	43.4	63.9
ORGANIC N MG/M3	1897.00	1083.00	99.7	94.7
TP-ORTHO-P MG/M3	77.00	111.00	83.9	91.6
ANTILOG PC-1	2341.09	976.72	95.8	85.4
ANTILOG PC-2	18.09	17.33	97.5	97.0
(N - 150) / P	8.73	21.23	16.4	62.8
INORGANIC N / P	1.47	1208.75	.1	100.0
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.40	7.7	1.7
CHL-A * SECCHI	48.43	46.29	98.6	98.4
CHL-A / TOTAL P	.23	.32	58.9	78.5
FREQ(CHL-a>10) %	98.97	94.52	.0	.0
FREQ(CHL-a>20) %	88.42	68.52	.0	.0
FREQ(CHL-a>30) %	70.61	43.17	.0	.0
FREQ(CHL-a>40) %	53.11	26.24	.0	.0
FREQ(CHL-a>50) %	38.89	15.96	.0	.0
FREQ(CHL-a>60) %	28.23	9.85	.0	.0
CARLSON TSI-P	82.25	70.68	.0	.0
CARLSON TSI-CHLA	69.15	64.81	.0	.0
CARLSON TSI-SEC	60.71	54.98	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: No Septic Reductions/ 10% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	228.99	95.7	95.9
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	140.77	94.9	95.7
CHL-A MG/M3	50.88	45.79	98.6	98.0
SECCHI M	.95	.98	43.4	44.7
ORGANIC N MG/M3	1897.00	1381.90	99.7	98.2
TP-ORTHO-P MG/M3	77.00	134.34	83.9	94.3
ANTILOG PC-1	2341.09	2019.08	95.8	94.6
ANTILOG PC-2	18.09	16.05	97.5	95.9
(N - 150) / P	8.73	9.35	16.4	19.0
INORGANIC N / P	1.47	9.61	.1	12.8
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	2.03	7.7	7.1
CHL-A * SECCHI	48.43	44.68	98.6	98.2
CHL-A / TOTAL P	.23	.20	58.9	51.3
FREQ(CHL-a>10) %	98.97	98.40	.0	.0
FREQ(CHL-a>20) %	88.42	84.76	.0	.0
FREQ(CHL-a>30) %	70.61	64.51	.0	.0
FREQ(CHL-a>40) %	53.11	46.33	.0	.0
FREQ(CHL-a>50) %	38.89	32.57	.0	.0
FREQ(CHL-a>60) %	28.23	22.78	.0	.0
CARLSON TSI-P	82.25	82.50	.0	.0
CARLSON TSI-CHLA	69.15	68.11	.0	.0
CARLSON TSI-SEC	60.71	60.35	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: No Septic Reductions/ 20% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	218.74	95.7	95.4
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	138.29	94.9	95.5
CHL-A MG/M3	50.88	45.29	98.6	98.0
SECCHI M	.95	.99	43.4	45.4
ORGANIC N MG/M3	1897.00	1370.53	99.7	98.1
TP-ORTHO-P MG/M3	77.00	133.45	83.9	94.2
ANTILOG PC-1	2341.09	1967.10	95.8	94.4
ANTILOG PC-2	18.09	16.11	97.5	96.0
(N - 150) / P	8.73	9.79	16.4	20.9
INORGANIC N / P	1.47	10.80	.1	15.4
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	2.00	7.7	6.8
CHL-A * SECCHI	48.43	44.82	98.6	98.2
CHL-A / TOTAL P	.23	.21	58.9	53.4
FREQ(CHL-a>10) %	98.97	98.33	.0	.0
FREQ(CHL-a>20) %	88.42	84.34	.0	.0
FREQ(CHL-a>30) %	70.61	63.85	.0	.0
FREQ(CHL-a>40) %	53.11	45.63	.0	.0
FREQ(CHL-a>50) %	38.89	31.93	.0	.0
FREQ(CHL-a>60) %	28.23	22.25	.0	.0
CARLSON TSI-P	82.25	81.84	.0	.0
CARLSON TSI-CHLA	69.15	68.01	.0	.0
CARLSON TSI-SEC	60.71	60.15	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: No Septic Reductions/ 30% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	208.02	95.7	94.9
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	135.46	94.9	95.2
CHL-A MG/M3	50.88	44.71	98.6	97.9
SECCHI M	.95	1.01	43.4	46.3
ORGANIC N MG/M3	1897.00	1357.30	99.7	98.0
TP-ORTHO-P MG/M3	77.00	132.41	83.9	94.1
ANTILOG PC-1	2341.09	1908.15	95.8	94.1
ANTILOG PC-2	18.09	16.19	97.5	96.0
(N - 150) / P	8.73	10.30	16.4	23.1
INORGANIC N / P	1.47	12.36	.1	18.9
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.97	7.7	6.4
CHL-A * SECCHI	48.43	44.97	98.6	98.2
CHL-A / TOTAL P	.23	.21	58.9	55.8
FREQ(CHL-a>10) %	98.97	98.24	.0	.0
FREQ(CHL-a>20) %	88.42	83.84	.0	.0
FREQ(CHL-a>30) %	70.61	63.07	.0	.0
FREQ(CHL-a>40) %	53.11	44.80	.0	.0
FREQ(CHL-a>50) %	38.89	31.19	.0	.0
FREQ(CHL-a>60) %	28.23	21.64	.0	.0
CARLSON TSI-P	82.25	81.12	.0	.0
CARLSON TSI-CHLA	69.15	67.88	.0	.0
CARLSON TSI-SEC	60.71	59.92	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: No Septic Reductions/ 40% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	196.79	95.7	94.2
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	132.20	94.9	94.9
CHL-A MG/M3	50.88	44.03	98.6	97.8
SECCHI M	.95	1.03	43.4	47.3
ORGANIC N MG/M3	1897.00	1341.74	99.7	97.9
TP-ORTHO-P MG/M3	77.00	131.20	83.9	94.0
ANTILOG PC-1	2341.09	1840.80	95.8	93.8
ANTILOG PC-2	18.09	16.28	97.5	96.1
(N - 150) / P	8.73	10.88	16.4	25.6
INORGANIC N / P	1.47	14.48	.1	23.5
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.93	7.7	6.0
CHL-A * SECCHI	48.43	45.14	98.6	98.2
CHL-A / TOTAL P	.23	.22	58.9	58.2
FREQ(CHL-a>10) %	98.97	98.13	.0	.0
FREQ(CHL-a>20) %	88.42	83.22	.0	.0
FREQ(CHL-a>30) %	70.61	62.13	.0	.0
FREQ(CHL-a>40) %	53.11	43.83	.0	.0
FREQ(CHL-a>50) %	38.89	30.32	.0	.0
FREQ(CHL-a>60) %	28.23	20.92	.0	.0
CARLSON TSI-P	82.25	80.32	.0	.0
CARLSON TSI-CHLA	69.15	67.73	.0	.0
CARLSON TSI-SEC	60.71	59.64	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: No Septic Reductions/ 50% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	184.94	95.7	93.3
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	128.43	94.9	94.5
CHL-A MG/M3	50.88	43.21	98.6	97.6
SECCHI M	.95	1.05	43.4	48.5
ORGANIC N MG/M3	1897.00	1323.14	99.7	97.8
TP-ORTHO-P MG/M3	77.00	129.75	83.9	93.8
ANTILOG PC-1	2341.09	1763.10	95.8	93.4
ANTILOG PC-2	18.09	16.38	97.5	96.2
(N - 150) / P	8.73	11.58	16.4	28.6
INORGANIC N / P	1.47	17.55	.1	29.8
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.89	7.7	5.6
CHL-A * SECCHI	48.43	45.33	98.6	98.2
CHL-A / TOTAL P	.23	.23	58.9	60.9
FREQ(CHL-a>10) %	98.97	97.98	.0	.0
FREQ(CHL-a>20) %	88.42	82.45	.0	.0
FREQ(CHL-a>30) %	70.61	60.98	.0	.0
FREQ(CHL-a>40) %	53.11	42.64	.0	.0
FREQ(CHL-a>50) %	38.89	29.27	.0	.0
FREQ(CHL-a>60) %	28.23	20.06	.0	.0
CARLSON TSI-P	82.25	79.42	.0	.0
CARLSON TSI-CHLA	69.15	67.55	.0	.0
CARLSON TSI-SEC	60.71	59.31	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: No Septic Reductions/ 60% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	172.34	95.7	92.3
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	123.98	94.9	94.0
CHL-A MG/M3	50.88	42.22	98.6	97.5
SECCHI M	.95	1.08	43.4	49.9
ORGANIC N MG/M3	1897.00	1300.51	99.7	97.6
TP-ORTHO-P MG/M3	77.00	127.98	83.9	93.7
ANTILOG PC-1	2341.09	1672.39	95.8	92.9
ANTILOG PC-2	18.09	16.50	97.5	96.3
(N - 150) / P	8.73	12.43	16.4	32.3
INORGANIC N / P	1.47	22.34	.1	38.7
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.84	7.7	5.0
CHL-A * SECCHI	48.43	45.54	98.6	98.3
CHL-A / TOTAL P	.23	.24	58.9	63.7
FREQ(CHL-a>10) %	98.97	97.79	.0	.0
FREQ(CHL-a>20) %	88.42	81.47	.0	.0
FREQ(CHL-a>30) %	70.61	59.54	.0	.0
FREQ(CHL-a>40) %	53.11	41.18	.0	.0
FREQ(CHL-a>50) %	38.89	28.00	.0	.0
FREQ(CHL-a>60) %	28.23	19.03	.0	.0
CARLSON TSI-P	82.25	78.41	.0	.0
CARLSON TSI-CHLA	69.15	67.32	.0	.0
CARLSON TSI-SEC	60.71	58.91	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: No Septic Reductions/ 70% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	158.90	95.7	90.9
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	118.68	94.9	93.3
CHL-A MG/M3	50.88	40.99	98.6	97.2
SECCHI M	.95	1.12	43.4	51.8
ORGANIC N MG/M3	1897.00	1272.47	99.7	97.4
TP-ORTHO-P MG/M3	77.00	125.79	83.9	93.4
ANTILOG PC-1	2341.09	1565.56	95.8	92.2
ANTILOG PC-2	18.09	16.64	97.5	96.5
(N - 150) / P	8.73	13.48	16.4	36.7
INORGANIC N / P	1.47	30.79	.1	51.4
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.77	7.7	4.5
CHL-A * SECCHI	48.43	45.77	98.6	98.3
CHL-A / TOTAL P	.23	.26	58.9	66.7
FREQ(CHL-a>10) %	98.97	97.53	.0	.0
FREQ(CHL-a>20) %	88.42	80.17	.0	.0
FREQ(CHL-a>30) %	70.61	57.68	.0	.0
FREQ(CHL-a>40) %	53.11	39.33	.0	.0
FREQ(CHL-a>50) %	38.89	26.42	.0	.0
FREQ(CHL-a>60) %	28.23	17.76	.0	.0
CARLSON TSI-P	82.25	77.23	.0	.0
CARLSON TSI-CHLA	69.15	67.03	.0	.0
CARLSON TSI-SEC	60.71	58.41	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: No Septic Reductions/ 80% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	144.36	95.7	89.0
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	112.24	94.9	92.4
CHL-A MG/M3	50.88	39.42	98.6	96.9
SECCHI M	.95	1.17	43.4	54.1
ORGANIC N MG/M3	1897.00	1236.76	99.7	97.0
TP-ORTHO-P MG/M3	77.00	123.00	83.9	93.1
ANTILOG PC-1	2341.09	1437.68	95.8	91.2
ANTILOG PC-2	18.09	16.81	97.5	96.6
(N - 150) / P	8.73	14.84	16.4	42.1
INORGANIC N / P	1.47	49.39	.1	69.6
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.70	7.7	3.8
CHL-A * SECCHI	48.43	46.00	98.6	98.3
CHL-A / TOTAL P	.23	.27	58.9	69.9
FREQ(CHL-a>10) %	98.97	97.15	.0	.0
FREQ(CHL-a>20) %	88.42	78.37	.0	.0
FREQ(CHL-a>30) %	70.61	55.21	.0	.0
FREQ(CHL-a>40) %	53.11	36.94	.0	.0
FREQ(CHL-a>50) %	38.89	24.40	.0	.0
FREQ(CHL-a>60) %	28.23	16.17	.0	.0
CARLSON TSI-P	82.25	75.85	.0	.0
CARLSON TSI-CHLA	69.15	66.65	.0	.0
CARLSON TSI-SEC	60.71	57.78	.0	.0

CASE: Cottonwood Lake

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: No Septic Reductions/ 90% Medicine

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	225.00	128.43	95.7	86.3
TOTAL N MG/M3	2115.00	2291.76	87.8	90.2
C.NUTRIENT MG/M3	132.40	104.24	94.9	91.0
CHL-A MG/M3	50.88	37.36	98.6	96.4
SECCHI M	.95	1.24	43.4	57.1
ORGANIC N MG/M3	1897.00	1189.72	99.7	96.4
TP-ORTHO-P MG/M3	77.00	119.33	83.9	92.7
ANTILOG PC-1	2341.09	1282.19	95.8	89.7
ANTILOG PC-2	18.09	17.00	97.5	96.8
(N - 150) / P	8.73	16.68	16.4	48.9
INORGANIC N / P	1.47	121.16	.1	92.1
TURBIDITY 1/M	2.40	2.40	94.1	94.1
ZMIX * TURBIDITY	4.76	4.76	70.2	70.2
ZMIX / SECCHI	2.08	1.60	7.7	3.0
CHL-A * SECCHI	48.43	46.22	98.6	98.4
CHL-A / TOTAL P	.23	.29	58.9	73.3
FREQ(CHL-a>10) %	98.97	96.53	.0	.0
FREQ(CHL-a>20) %	88.42	75.74	.0	.0
FREQ(CHL-a>30) %	70.61	51.76	.0	.0
FREQ(CHL-a>40) %	53.11	33.72	.0	.0
FREQ(CHL-a>50) %	38.89	21.77	.0	.0
FREQ(CHL-a>60) %	28.23	14.14	.0	.0
CARLSON TSI-P	82.25	74.16	.0	.0
CARLSON TSI-CHLA	69.15	66.12	.0	.0
CARLSON TSI-SEC	60.71	56.94	.0	.0

Appendix J. TMDL Summary

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

COTTONWOOD LAKE

MEDICINE CREEK WATERSHED

(HUC 10160009)

FAULK, HAND, SPINK COUNTIES, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

FEBRUARY, 2001

Cottonwood Lake Total Maximum Daily Load

Waterbody Type:	**Lake (Natural)**
303(d) Listing Parameter:	**TSI Trend, pH**
Designated Uses:	**Recreation, Warmwater Marginal Aquatic Life**
Size of Waterbody:	**1,649 acres**
Size of Watershed :	**135,223 acres**
Water Quality Standards:	**Narrative and Numeric**
Indicators:	**Average TSI, water chemistry**
Analytical Approach:	**AGNPS, BATHTUB, FLUX, PSIAC**
Location:	**HUC Code: 10160009**
Goal:	**30 Percent reduction in the phosphorus load**
Target:	**TSI of 68 and phosphorus limited**

Objective:

The intent of this summary is to clearly identify the components of the TMDL submittal to support adequate public participation and facilitate the US Environmental Protection Agency (EPA) review and approval. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

Introduction

Cottonwood Lake is a 1,649-acre natural impoundment located in southwestern Spink County, South Dakota. The 1998 South Dakota 303(d) Waterbody List (page 21) identified Cottonwood Lake for TMDL development for trophic state index (TSI), with an increasing eutrophication trend, and high pH levels.

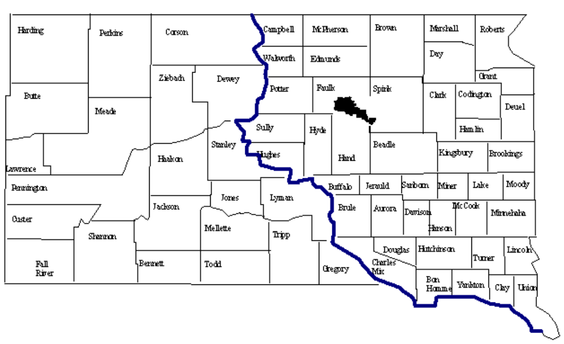


Figure 49. Watershed Location in South Dakota

The lake reaches a maximum depth of 9.0 feet (2.7 m) and holds a total water volume of 10,722 acre-ft. It is a natural basin, however, the lake outlet has been modified to maintain a more stable lake level as well as a greater volume of water. The only major tributary to the lake enters on the south end of the lake and flows out through the north end. Due to its shallow nature, the lake is not subject to stratification.

Problem Identification

Medicine Creek is the primary tributary to Cottonwood Lake and predominantly drains grazing lands with some cropland acres. Winter feeding areas for livestock are present in the watershed. The stream carries sediment and nutrient loads, which degrade water quality in the lake and increases eutrophication. An estimated 5,894 kg of phosphorus enter Cottonwood Lake from Medicine Creek every year.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

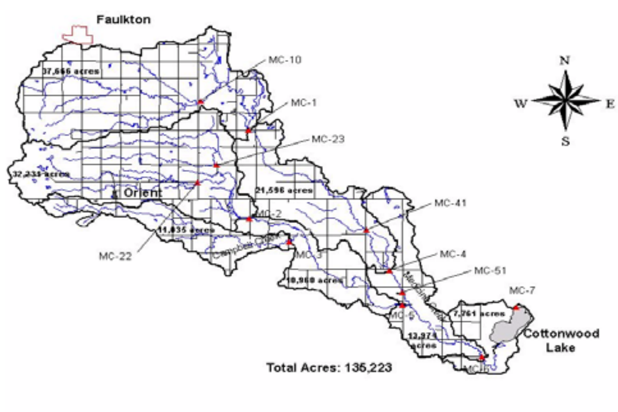
Cottonwood Lake has been assigned beneficial uses by the state of South Dakota Surface Water Quality Standards regulations. Along with these assigned uses are narrative and numeric criteria that define the desired water quality of the lake. These criteria must be maintained for the lake to satisfy its assigned beneficial uses, which are listed below:

Warmwater marginal fish life propagation;
Immersion recreation;
Limited contact recreation; and

Fish and wildlife propagation, recreation and stock watering.

Individual parameters, including the lake's TSI value, determine the support of beneficial uses and compliance with standards. A gradual increase in fertility of the water due to nutrients washing into the lake from external sources is a sign of the eutrophication process. Cottonwood Lake experiences this and is identified in both the 1998 South Dakota Waterbody List and "Ecoregion Targeting for Impaired Lakes in South Dakota" as not supporting its aquatic life beneficial use.

South Dakota has several applicable narrative standards that may be applied to the undesired eutrophication of lakes and streams. Administrative Rules of South Dakota Article 74:51 contains language that prohibits the existence of materials causing pollutants to form, visible pollutants, taste and odor producing materials, and nuisance aquatic life.



Watershed

If adequate numeric criteria are not available, the South Dakota Department of Environment and Natural Resources (SD DENR) uses surrogate measures to indicate impairment. To assess the trophic status of a lake, SD DENR uses the mean Trophic State Index or TSI (Carlson, 1977) which incorporates secchi depth, chlorophyll a concentrations and phosphorus concentrations. SD DENR has developed an EPA approved protocol that establishes desired TSI levels for lakes based on an ecoregion approach. This protocol was used to assess impairment and determine a numeric target for Cottonwood Lake.

Cottonwood Lake currently has a mean TSI of 70.07, which is indicative of high levels of primary productivity. Assessment monitoring indicates that the primary cause of the high productivity is high phosphorus loads from the watershed.

A 65% reduction in phosphorus loads from Medicine Creek along with a 100% reduction in septic system loads would be required to bring Cottonwood Lake to a condition in which it fully supports its beneficial uses as well as bringing it from a hyper-eutrophic condition to a eutrophic condition. A 65% reduction would be difficult at best to achieve. A more realistic 30% reduction from Medicine Creek in combination with a 50% reduction from septic systems will bring the lake to a phosphorus-limited state that partially supports its beneficial uses. The numeric target established to improve the trophic state of Cottonwood Lake is a TSI of 68, which will require a 30% reduction in phosphorus loading to the lake.

Additional benefits to the reduced phosphorus concentrations include lower pH levels. While the pH of Cottonwood Lake did not exceed the state standards during the project, levels were often found to be at or near the maximum allowable values. High alkalinity in the lake likely buffers the maximum levels. Reduction in algal blooms should result in a lower average pH for the lake.

Pollutant Assessment

Point Sources

There are no point sources of pollutants of concern in this watershed.

Nonpoint Sources/ Background Sources

Analysis of the watershed through the use of the Agricultural Non Point Source (AGNPS) model indicated that approximately 39% of the phosphorus entering the lake is the result of feeding area discharge. See the AGNPS section of the final report, pages 13-14.

Analysis of the watershed through the use of the Pacific Southwest Inter Agency (PSIAC) model indicated that approximately 5% of the phosphorus entering the lake and 11% of the sediment entering the lake may be attributed to inadequate rangeland and cropland management practices. See the PSIAC section of the final report, pages 11-12.
An additional 4% of the phosphorus load may be attributed to the individual waste water treatment systems located around the lake. See the septic survey section of the final report, pages 9-10.

The remaining 17% of the phosphorus loading to Cottonwood Lake may be attributed to background sources in the watershed.

Linkage Analysis

Water quality data was collected from 7 monitoring sites within the Cottonwood Lake/Medicine Creek watershed. Samples collected at each site were taken according to South Dakota's EPA approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on 10% of the samples according to South Dakota's EPA approved Clean Lakes Quality Assurance/Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed on pages 18-72 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The PSIAC (Pacific Southwest Inter Agency) model was used to estimate potential sediment load reductions from the watershed through the implementation of various best management practices. See the PSIAC section of the final report, pages 11-12.

The AGNPS (Agriculture Nonpoint Pollution Source) feeding area subroutine was used to provide comparative values for each of the animal feeding operations located in the watershed. See the AGNPS section of the final report, pages 13-14.

The impacts of phosphorus reductions on the condition of Cottonwood Lake were calculated using BATHTUB, an Army Corps of Engineers model. The model predicted that reductions of phosphorus loadings to the lake by 30 percent will result in a shift in the nutrient balance from nitrogen to phosphorus limited. This would also result in a TSI score that partially restores support of the beneficial uses to the lake. Reductions of 67% would result in a TSI score that fully restores support of the beneficial uses of the lake. A discussion of the reduction response modeling may be found on pages 75-76 of the final assessment report.

TMDL and Allocations

TMDL

	0 kg/yr.	(WLA)
+	1,060 kg/yr.	(LA)
+	3,065 kg/yr.	(Background)
+	1,060 kg/yr.	(MOS)
	4,125 kg/yr.	(TMDL)

Wasteload Allocations (WLAs)

There are no point sources of pollutants of concern in this watershed. Therefore, the "wasteload allocation" component of these TMDLs is considered a zero value. The TMDLs are considered wholly included within the "load allocation" component.

Load Allocations (LAs)

The results of the PSIAC model indicates that a 5% (294.7 kg/yr.)

reduction in phosphorus loading and 11% reduction in sediment loading to the lake could be achieved by improved rangeland and cropland management on about 24,212 acres and 10,540 acres (respectively) within the watershed. See the PSIAC section of the final report, pages 11-12.

Removal of all the animal feeding operations within the watershed would account for an additional 39% (2,298.7 kg/yr.) of the phosphorus load to the lake. See the AGNPS section of the final report, pages 13-14.

Individual wastewater treatment systems account for 4% (235.8 kg/yr.) of the phosphorus load allocation.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation and agricultural practices. To determine seasonal differences, Cottonwood Lake samples were separated into spring (March-May), summer (June-August), fall (September-November), and winter (December-February) collection periods.

Margin of Safety

An 18 percent margin of safety is built into the TMDL through completion of practices that would reduce all of the phosphorus loading discussed in the load allocations section.

An additional margin of safety is implicit as conservative estimations were used in the development of the phosphorus loads originating from the individual wastewater treatment systems and from the rangeland and cropland best management practices applied in the PSIAC model. This is addressed in greater detail on pages 9-12 of the assessment final report.

Stabilization of 2,640 linear feet of eroding lakeshore are not accounted for in the loading estimates for the lake and will also reduce suspended solids and associated total phosphorus.

Critical Conditions

The impairments to Cottonwood Lake are most severe during the late summer. This is the result of warm water temperatures and peak algal growth.

Follow-Up Monitoring

Monitoring and evaluation efforts will be targeted toward the effectiveness of implemented BMP's. Sample sites will be based on BMP site selection and parameters will be based on a product specific basis.

Monitoring will also take place prior to the construction at two of the 5 proposed agricultural waste systems and three times at the lake during each growing season. Samples will be collected both upstream and downstream of the proposed project area to measure impact of the specific site. Following construction, these sites will again be tested to measure the effectiveness of the agricultural waste management systems.

Once the implementation project is completed, post-implementation monitoring will be necessary to assure that the TMDL has been reached and improvement to the beneficial uses occurs.

Public Participation

Efforts taken to gain public education, review, and comment during development of the TMDL involved:

1. Central Plains Water Development District Board Meetings (8)
2. Spink County Conservation District Board Meetings (1)
3. Hand County Conservation District Board Meetings (7)
4. Faulk County Conservation District Board Meetings (1)
5. Cottonwood Lake Association Meetings (2)
6. Kiwanis Club of Miller South Dakota
   Individual contact with landowners in the watershed.

7. Articles in the local newspapers (3)

The findings from these public meetings and comments have been taken into consideration in development of the Cottonwood Lake TMDL.

Implementation Plan

The South Dakota DENR is working with the Hand County Conservation District and the Central Plains Water Development District to initiate an implementation project beginning in the spring of 2002. It is expected that a local sponsor will request project assistance during the fall 2001 EPA Section 319 funding round.

Fifty copies of this document were printed by the Department of Environment and Natural Resources at a cost of $5.70 per copy.